

WL-TR-95-2111

DEVELOPMENT OF A BIPOLAR LEAD/ACID
BATTERY FOR THE MORE ELECTRIC AIRCRAFT



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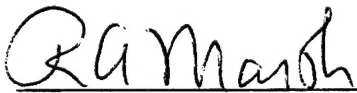
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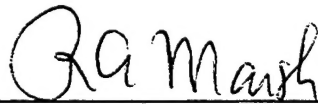
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13. ABSTRACT (Maximum 200 words) This report summarizes the development work completed under contract F33615-91-C-2142 for the time period of September 1991 to September 1995. Initial work targeted the development of a filled polymeric composite substrate for use in a true bipolar lead acid battery. Efforts were refocused on metallic substrate technology in Month 33, and concluded with the delivery of battery systems to Wright Laboratory.				
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1.0 SUMMARY

A 36-month contract was undertaken by Johnson Controls Battery Group, Inc. to develop a highly conductive, non-porous, and lightweight bipolar substrate and deliver a 56-volt prototype module for evaluation for the More Electric Aircraft. Eighteen months into Contract #F33615-91-C-2142, significant accomplishments were reported in the identification of suitable composite materials and in optimizing the compounding parameters of same. Laminated, 8 cm (L) x 8 cm (H) x 0.102 cm (TH) substrates with an overall resistivity of 4-6 Ω -cm were routinely manufactured in-house and used in battery builds. Over 150 cycles were demonstrated to 100% DOD at 0.16 A/cm² in a 4-volt battery configuration. Mass production oriented container molding was also demonstrated, however, process reliability was a major concern. Critical evaluation of the project in Month 33 recognized the difficulties in addressing recurrent substrate and paste adhesion delamination, as well as those to be solved in achieving high power (0.48+ A/cm²) capability from a 400+ cm² electrode. High power capability from a composite substrate was not deemed likely in the remaining contract period. Therefore, given its success in a parallel internally funded bipolar program, JCBGI requested a no-cost time extension to evaluate a new approach in metallic bipolar substrate technology. Five attempts were made at cladding strips of various corrosion resistant alloys, however, resultant materials were never suited to pasting or battery builds. Concurrent efforts to redesign the injection molded container succeeded in eliminating internal distortion of the metallic electrodes, but failed to resolve cell-to-cell leakage around the fill ports. At contract's end, deliverables utilizing a binary lead alloy and an alternative containment design were assembled, formed and delivered to WPAFB for test and evaluation.

Future composite bipolar substrate investigations based upon this body of work should focus on fostering positive paste adhesion. Continued metallic substrate work would benefit most from efforts to increase the substrate strength and corrosion resistance. Both designs require additional development of the injection molded containment concept to eliminate the catastrophic cell-to-cell leakage exhibited at the close of this contract.

2.0. WORK BREAKDOWN SCHEDULE

As with other contract work performed at JCBGI, a Work Breakdown Schedule (WBS) was implemented to plan, execute, and monitor technical progress, costs, and scheduling. Tasks were identified as unitary efforts necessary to complete individual aspects of battery development, and subtasks further delineated each task. Composite plans, shown in Figure 1, were easily translated in August 1994 to more closely describe the efforts necessary to assemble a 24-volt bipolar battery utilizing metallic based substrates. These interpretations are shown in parentheses next to the composite substrate counterparts within Figure 1.

FIGURE 1: BMET WORK BREAKDOWN SCHEDULE

WBS 1.0 PROGRAM MANAGEMENT

- Subtask 1.1 Managing Strategy
- Subtask 1.2 Liaison/Meetings
- Subtask 1.3 Documentation
- Subtask 1.4 Contract Administration
- Subtask 1.5 Operating Supplies

WBS 2.0 BATTERY DESIGN

- Subtask 2.1 Battery System Design Analysis
- Subtask 2.2 Performance Modeling

WBS 3.0 BIPOLAR PLATE

- Subtask 3.1 Conductive Fillers (Multi-Alloy Substrate Development)
- Subtask 3.2 Substrate Fabrication Processes (Rolling/Embossing Work)
- Subtask 3.3 Stability Testing (Corrosion Testing)
- Subtask 3.4 Proof of Concept Testing (Small Scale Characterization)

WBS 4.0 BATTERY COMPONENTS

- Subtask 4.1 Separator Material
- Subtask 4.2 Active Material Development (Freeze/Thaw Work)

WBS 5.0 BATTERY FABRICATION

- Subtask 5.1 Sealing Methods (Lead to Plastic Interface Seal)
- Subtask 5.2 Formation

WBS 6.0 BMET DEMONSTRATION

- Subtask 6.1 Battery Fabrication (Deliverables)
- Subtask 6.2 Testing (Group 34 Cycling)

3.0 COMPOSITE SUBSTRATE DEVELOPMENT

3.1 WBS 1.0 PROGRAM MANAGEMENT

3.1.1 Subtask 1.1 Managing Strategy

Five review meetings were scheduled and attended by WPAFB and JCBGI personnel. These dates, as well as milestones achieved during the composite development phase of the contract, are shown in Gantt chart form in Figure 2.

3.2 WBS 2.0 BATTERY DESIGN

3.2.1 Subtask 2.1 Battery System Design Analysis

Preliminary performance requirements for the More Electric Aircraft (MEA) energy source were given to JCBGI by Richard Flake of WPAFB during the program kickoff meeting on December 12, 1991. The following energy sources were required:

Main Engine Starting:	150 kW, 30 sec
Ground Power:	25-75 kW, 30-45 min
Emergency Power:	75 kW, 10 min
APU Starting:	5-10 kW, 15 sec
Hybrid Emergency:	50-75 kW, 60 sec
Temperature Range:	-65°F to 120°F
Voltage Window:	270 volts (min), 330 volts (max)

Given this, JCBGI proceeded to use its proprietary lead/acid battery mathematical model to design near- and far-term bipolar systems having 5- and 10- year development time frames. Near-term modeling assumed that substrate program goals were reached and conventional active materials were used. The 10-year battery systems were projected assuming a thinner, more conductive substrate and improved active materials. The results, shown in Figures 3 through 14, dramatically illustrate the system configuration's dependence on application. Designs required as little as 0.18 ft³ with a system mass of 33 pounds to as much as 8.13 ft³ and 1349 pounds.

3.3 WBS 3.0 BIPOLAR PLATE

3.3.1 Subtask 3.1 Conductive Fillers

Initial work was focused on identifying an electronically conductive, filled polymeric composite having negligible ionic conduction which could short adjacent cells. The substrate was likewise required to be chemically inert to the electrode reactions, to have high oxygen and hydrogen overpotentials in H₂SO₄, and to be readily manufactured.

FIGURE 2: Composite Development Gantt Chart with Milestones

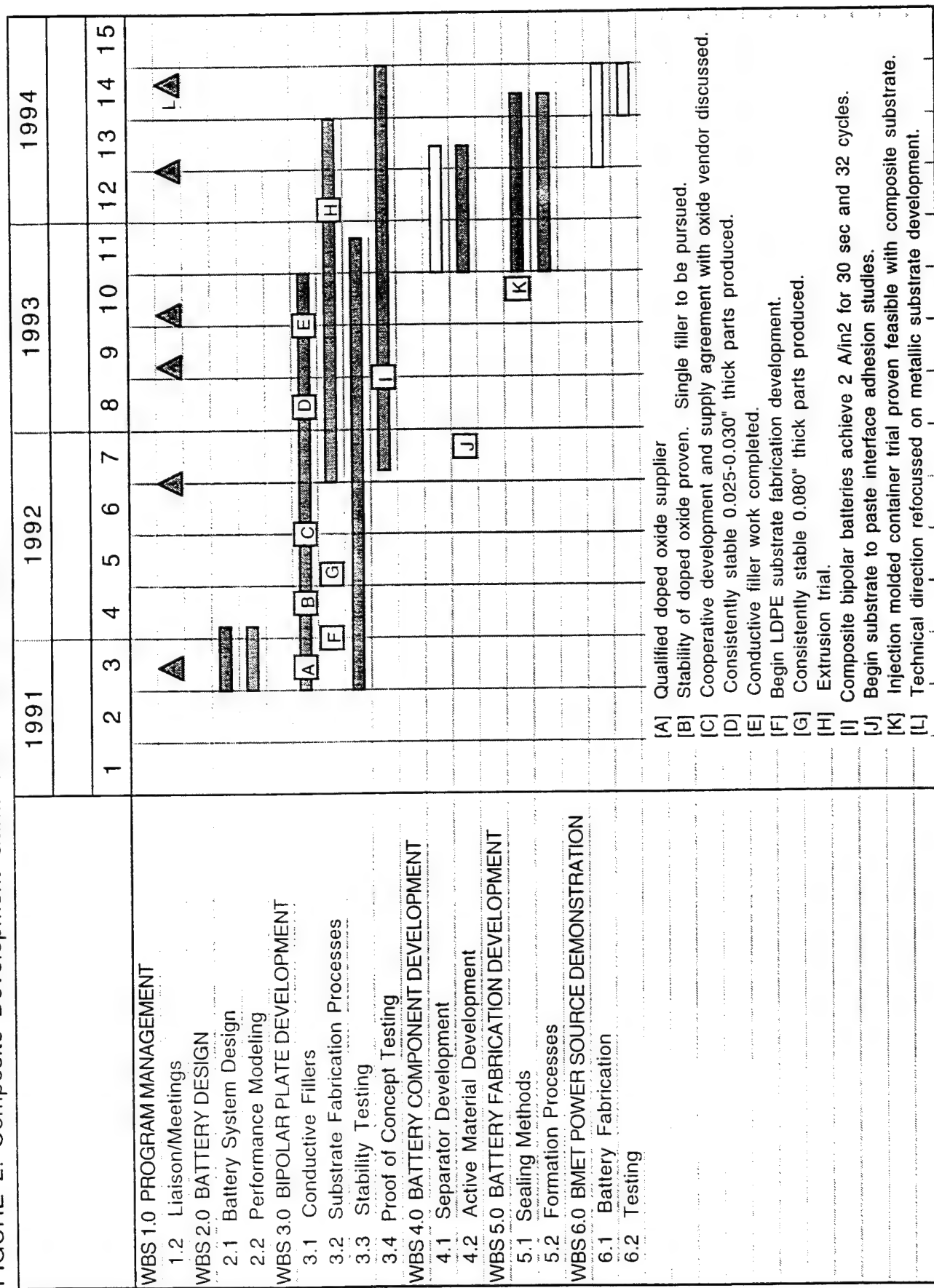


FIGURE 3

NEAR AND FAR TERM BMET BIPOLAR BATTERY SPECIFICATIONS

<u>BATTERY TYPE</u>	<u>NEAR TERM</u>	<u>FAR TERM</u>
Main Engine Starting		
Mass	450 lbs.	389 lbs.
Volume	2.45 ft³	2.00 ft³
Ground Power		
Lower Capacity Unit		
Mass	1000 lbs.	865 lbs.
Volume	6.15 ft³	4.85 ft³
Higher Capacity Unit		
Mass	1349 lbs.	1235 lbs
Volume	8.13 ft³	6.72 ft³
APU Starting		
Mass Volume	33.4 lbs.	30.6 lbs
Volume	0.18 ft³	0.16 ft³
Assumptions:		
Substrate Thickness	0.025"	0.010"
Substrate Weight	150 mg/cm²	80 mg/cm²
Substrate Resistivity	2.0 Ω-cm	~0 Ω-cm

FIGURE 4

BMET PERFORMANCE REQUIREMENTS
BIPOLAR BATTERY SPECIFICATIONS
Near Term Projections (within 5 years)
330 Volt Battery Systems

REQUIREMENTS MET	BATTERY DIMENSIONS	BATTERY VOLUME	BATTERY WEIGHT	W/kg	W/cm ³	W-hr/kg	W- hr/cm ³
Main Engine Starting APV Starting Hybrid Emergency	17.6"x15.5"x15.5"	2.45 ft ³	450 lbs	747.9	2.2	12.25	0.036
Main Engine Starting Ground Power Emergency Power APU Starting Hybrid Emergency							
Scenario 1 30 minute ground power capacity	27.4"x19.7"x19.7"	6.15 ft ³	1000 lbs	62.2	0.16	31.08	0.081
Scenario 2 45 minute ground power capacity	36.2"x19.7"x19.7"	8.13 ft ³	1349 lbs	46.1	0.12	34.56	0.092
APU Starting	16.5"x4.33"x4.33"	0.18 ft ³	33 lbs	705.0	2.1	11.75	0.036

FIGURE 5
 BMET PERFORMANCE REQUIREMENTS
 BIPOLAR BATTERY SPECIFICATIONS
 Far Term Projections (10 years)
 330 Volt Battery Systems

REQUIREMENTS MET	BATTERY DIMENSIONS	BATTERY VOLUME	BATTERY WEIGHT	W/kg	W/cm3	W-hr/kg	W- hr/cm3
Main Engine Starting APV Starting Hybrid Emergency	14.4"x15.5"x15.5"	2.00 ft3	389 lbs	895.3	2.8	14.17	0.044
Main Engine Starting Ground Power Emergency Power APU Starting Hybrid Emergency							
Scenario 1 30 minute ground power capacity	21.6"x19.7"x19.7"	4.85 ft3	864 lbs	72.0	0.21	35.97	0.103
Scenario 2 45 minute ground power capacity	29.9"x19.7"x19.7"	6.72 ft3	1235 lbs	50.6	0.15	37.77	0.111
APU Starting	15.2"x4.33"x4.33"	0.16 ft3	31 lbs	772.0	2.3	12.87	0.041

FIGURE 6
Comparison of Chemset and F2 Plates for
Main Engine Starting Battery

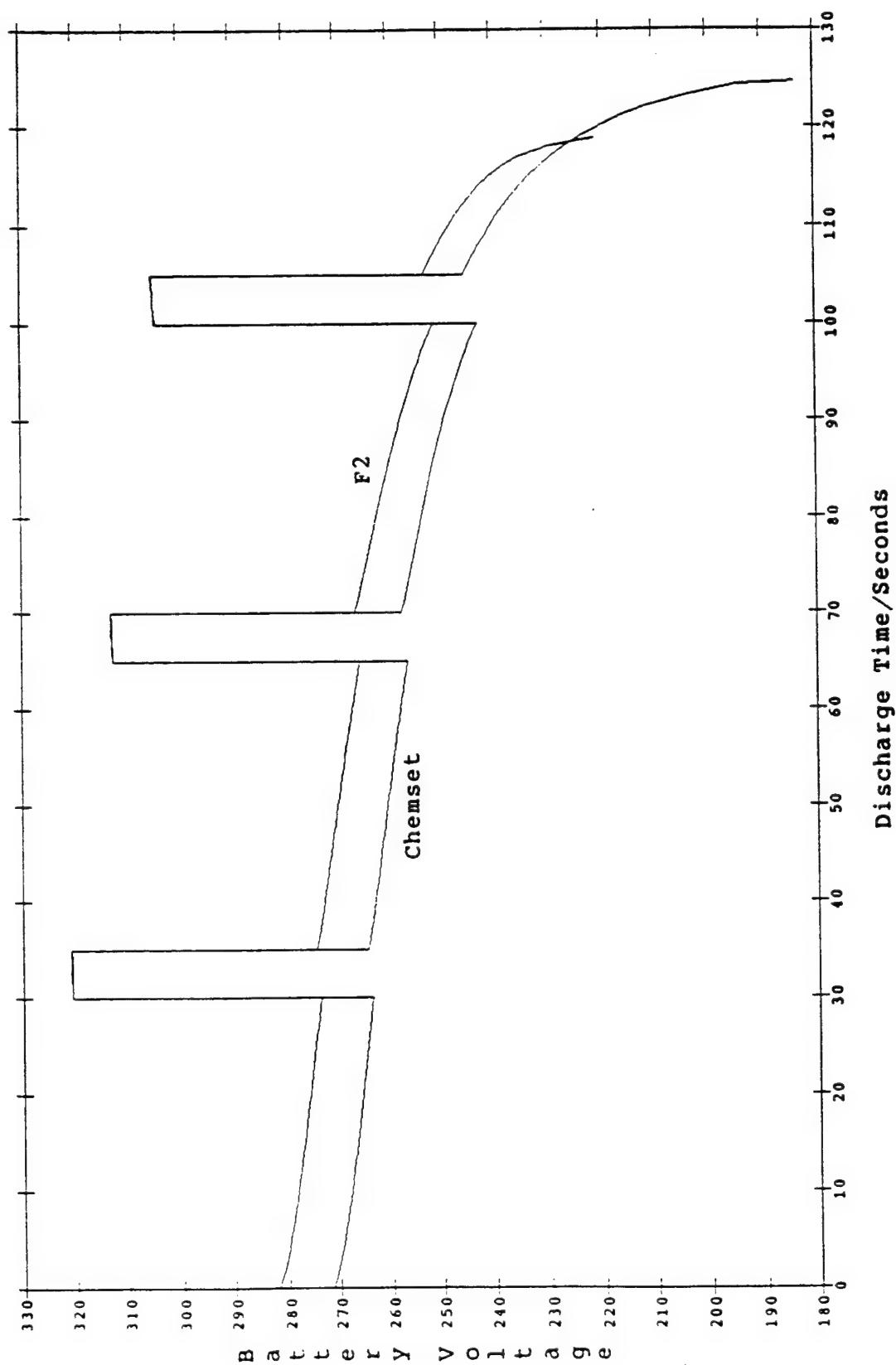


FIGURE 7
Effect of Temperature on Performance
of Main Engine Starting Battery

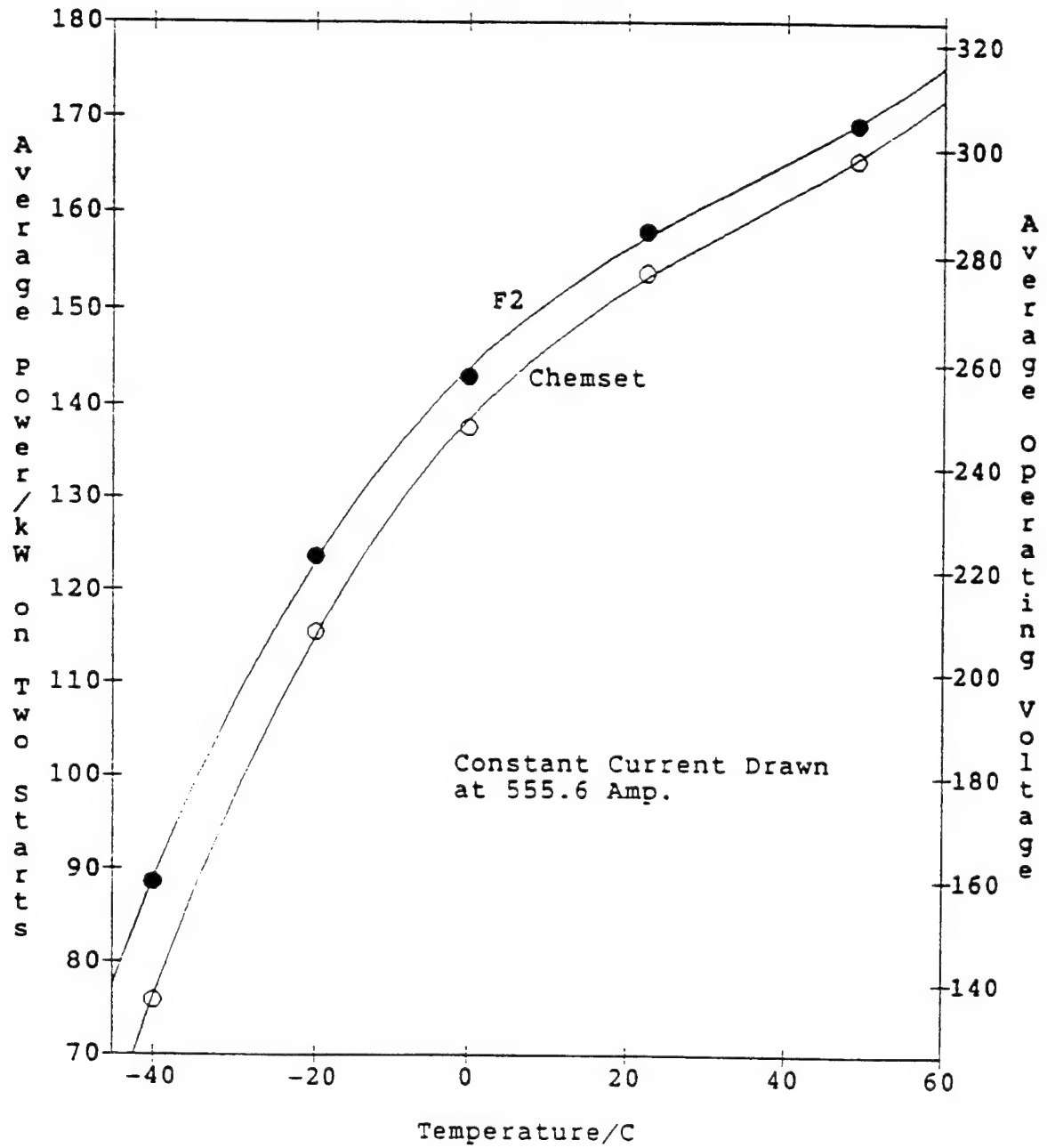


FIGURE 8
Comparison of Chemset and F2 Plates for
Ground Power Units

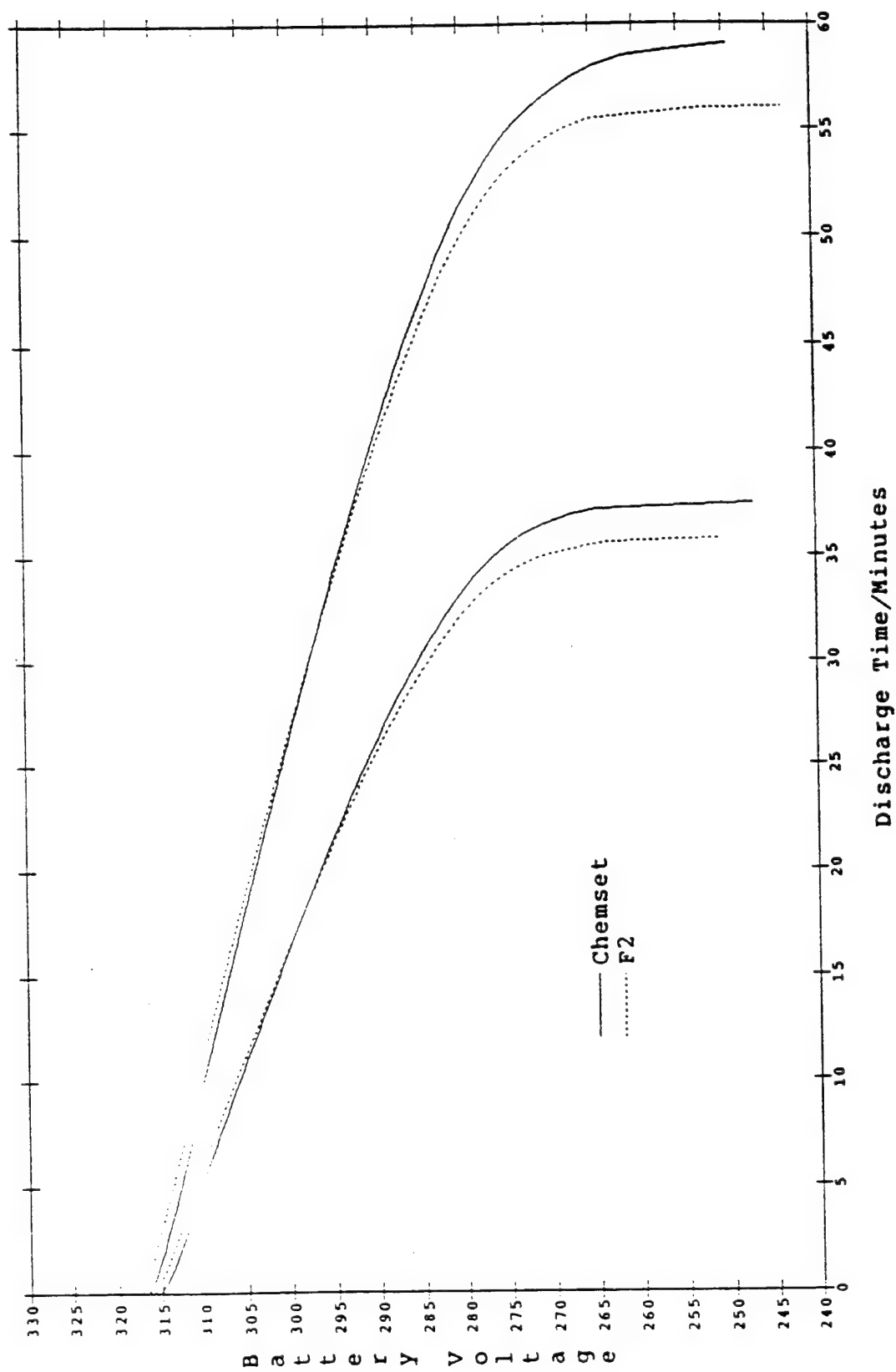


FIGURE 9
Effect of Temperature on Power Output
of the Ground Units

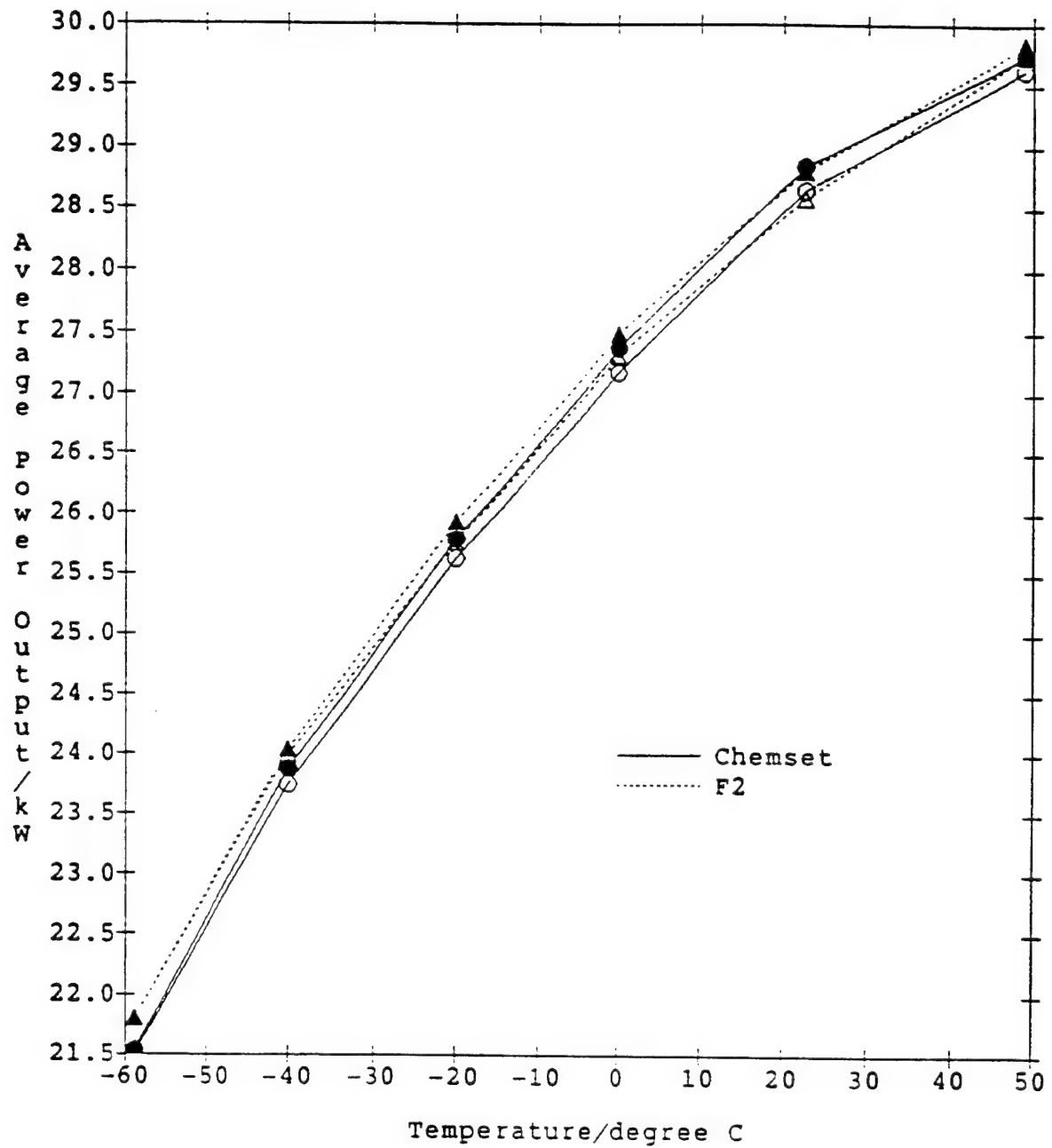


FIGURE 10
Effect of Temperature on Capacity of
the Ground Units

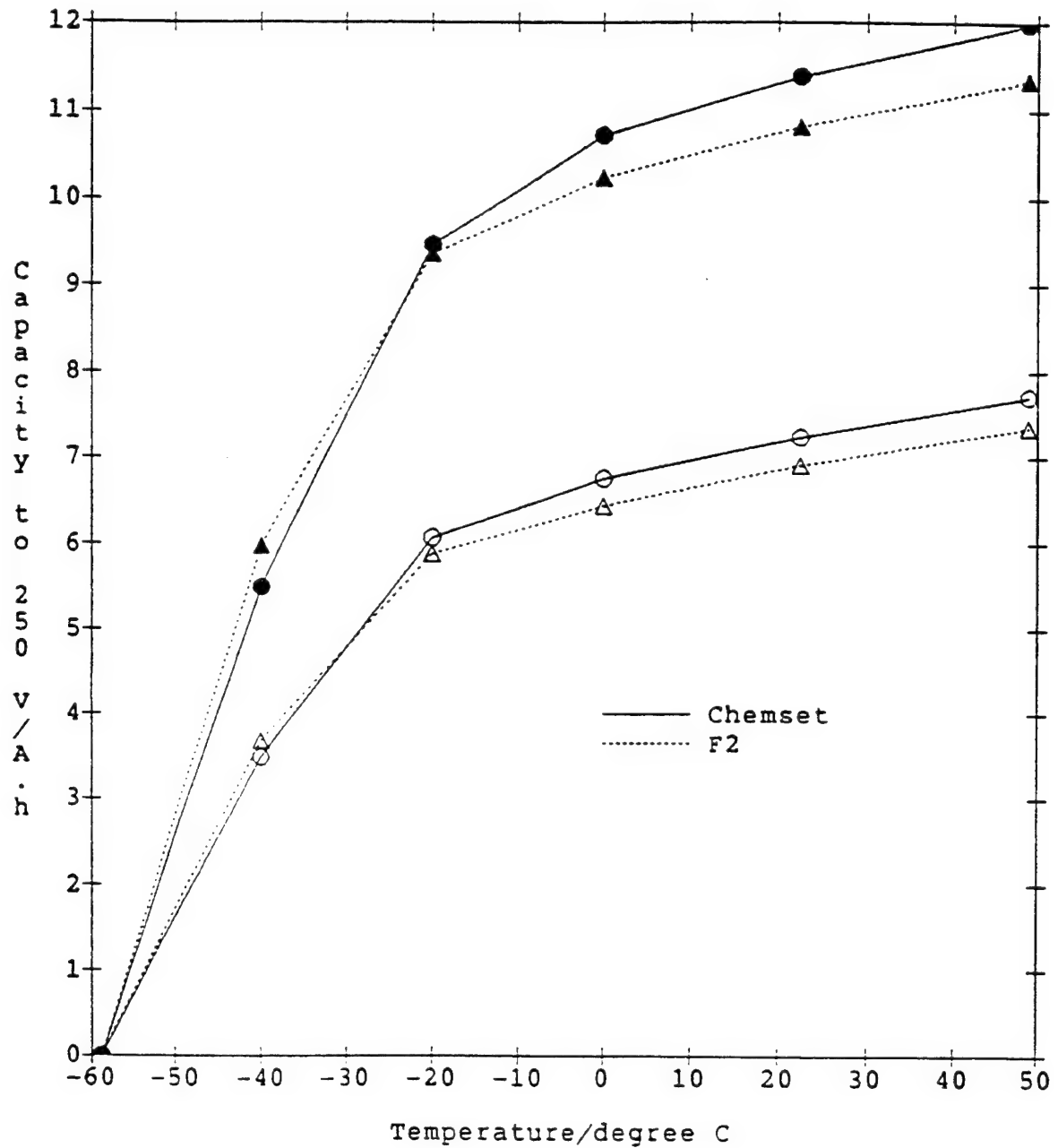


FIGURE 11
Comparison of Chemset and F2 Plates for
APU Starting Battery

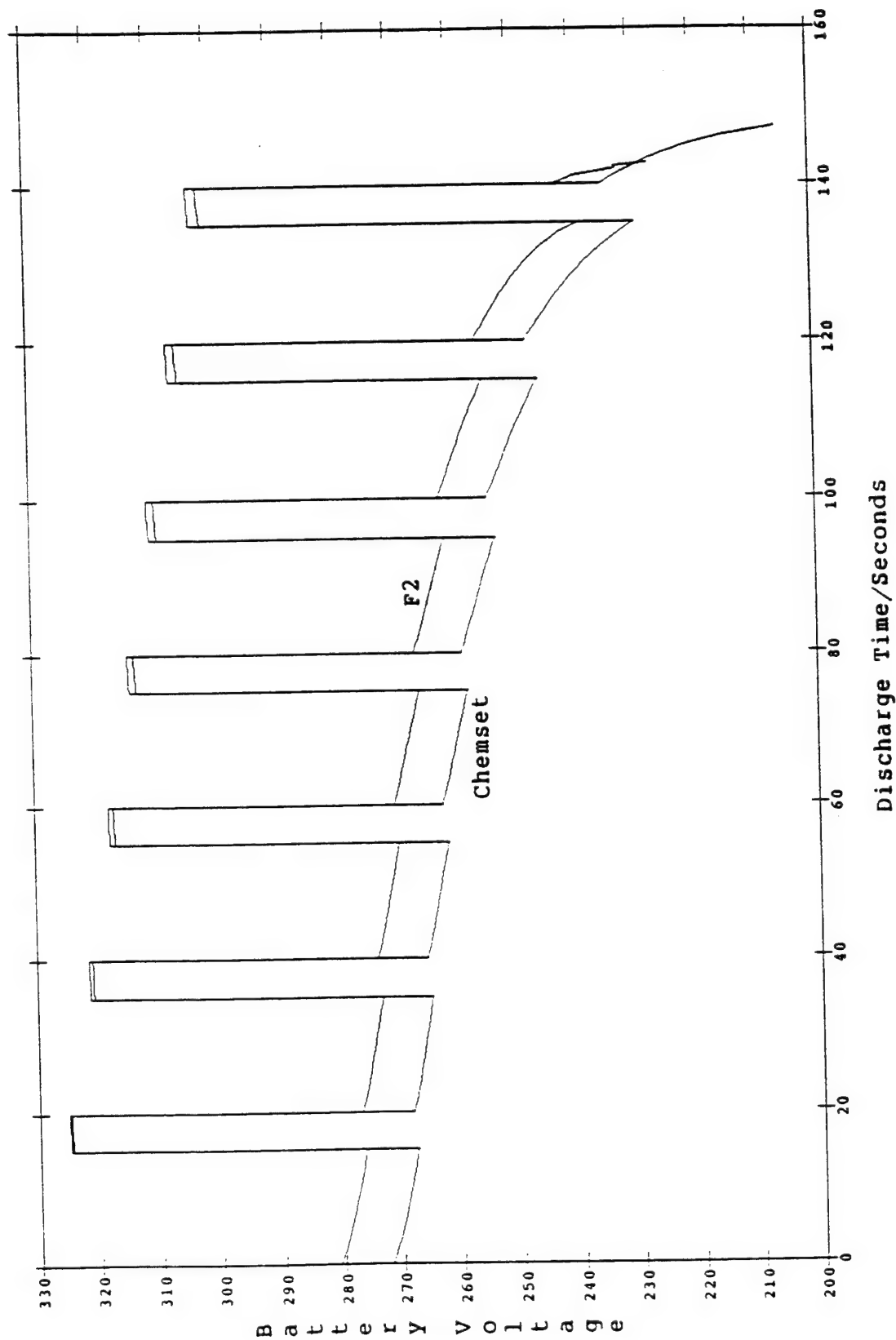


FIGURE 12
Effect of Temperature on Performance
of APU Starting Battery

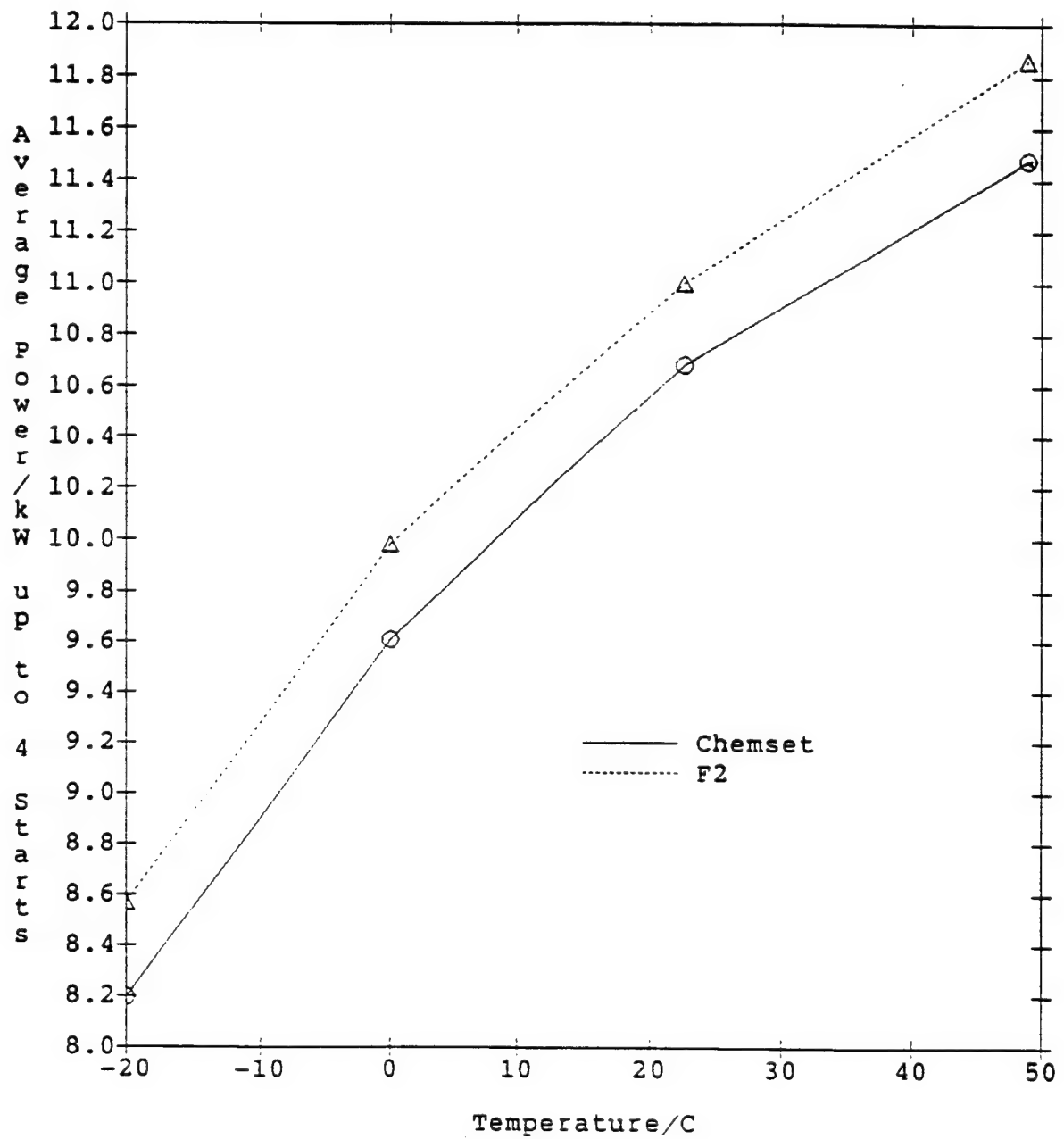


FIGURE 13
Comparison of Chemset and F2 Plates for
Emergency Power Unit

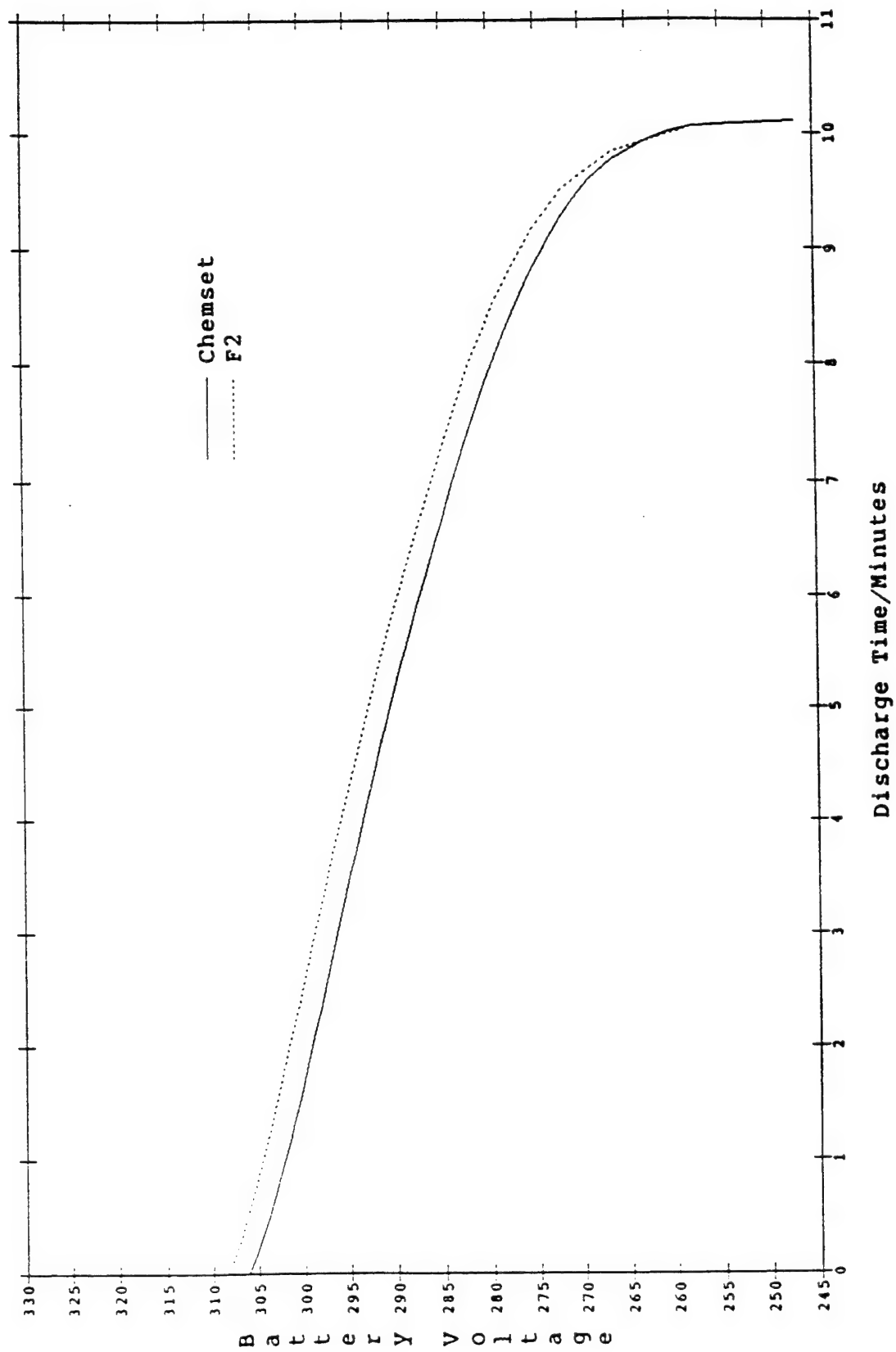
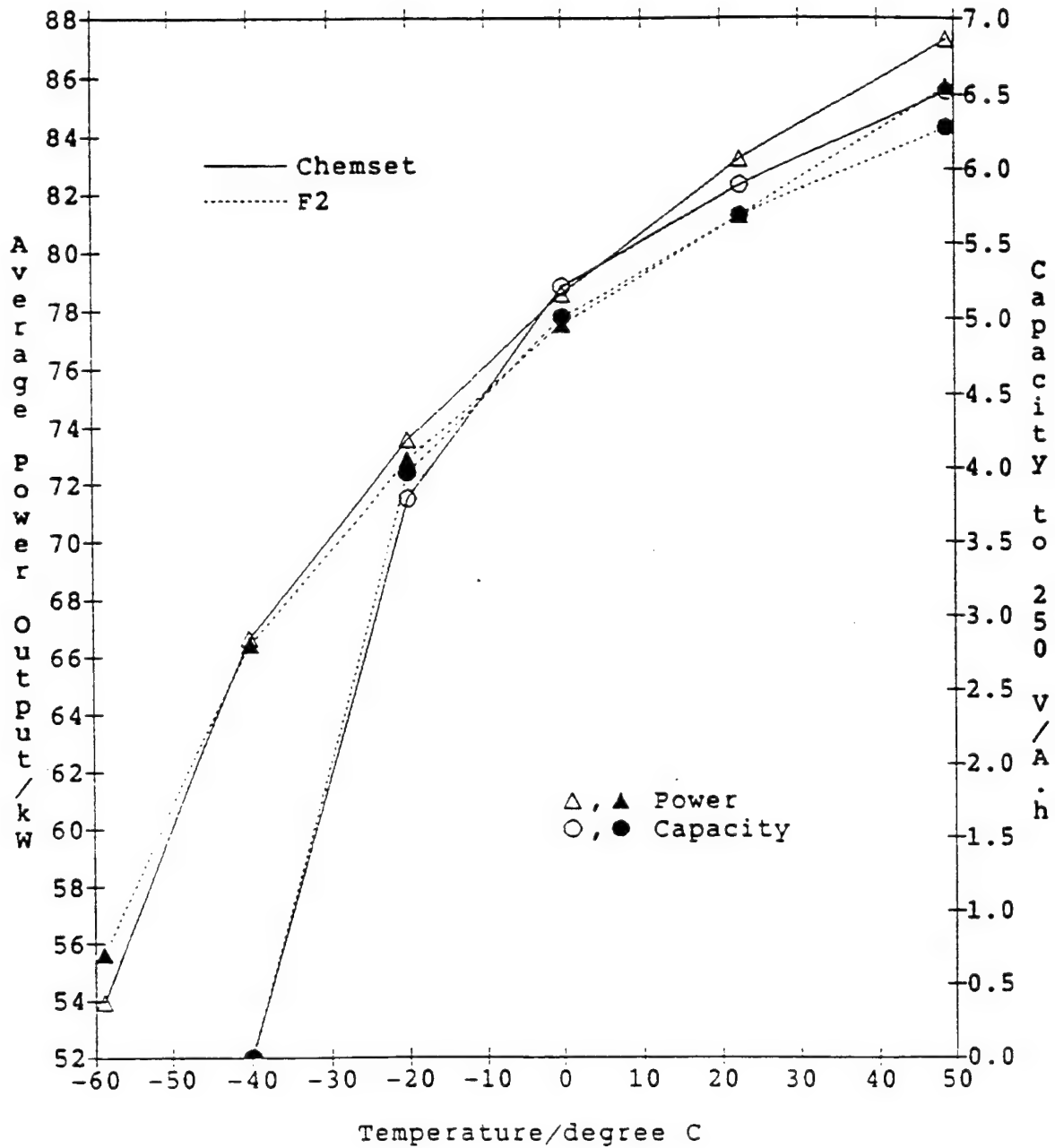


FIGURE 14
Effect of Temperature on Performance
of the Emergency Power Unit



Recognizing the recommendations from previous WPAFB work performed at JCBGI, conductive filler development resumed with further investigation of doped oxide. Coated glass fibers were also studied.

Initial work with Photon Energy Systems (PES) focused on coating doped oxide onto glass fibers. Four separate attempts were made with poor results. The first lot did not withstand the acid environment, and the second lacked uniformity and conductivity. Coated fibers from the third trial possessed no adhesion between the oxide and glass, hence were impossible to handle or compound into plastic. PES ultimately did coat 2-6" long fibers during a fourth trial, but was unable to supply the shorter lengths required for this application. Activity in this area was subsequently discontinued.

Efforts by Materials and Electrochemical Research, Inc. (MER) to produce a dense plaque of doped oxide met with similar difficulties. Prototype samples lost all conductivity and dissolved when put in contact with H_2SO_4 . A carbide compound was also provided, but found too resistive. No further attempts were made.

Two companies were next contacted for samples of doped oxide in powder form. Provided materials were extremely similar in particle size and appearance, and remained stable throughout acid leach testing. Replicate samples of 85% and 90% loaded plastic were then prepared. Measurements showed the oxide from Magnesium Elektron, Inc. (MEI) to be seven to fifteen times more conductive than that obtained from Crystal Research, Inc. (CRI). Throughout ensuing months, MEI recognized the product potential, entered into a joint development (JD) effort with JCBGI, and supplied over \$110,000 worth of oxide to JCBGI at no cost. Leftover material was returned per the appropriate clause in the JD. Additional oxides doped with other elements were prepared by MEI late in the contract, but shown highly resistive and unstable during JCBGI testing. MEI was also instrumental in providing compounding expertise that greatly expedited the development effort.

Particle size optimization was one such area in which MEI provided invaluable help. JCBGI initially believed that a smaller particle size (1 micron) would reduce porosity due to its being more easily wetted by the surrounding plastic resin. Trials using fines screened from the supplied material proved the contrary with regard to both conductivity and porosity. Resistivity readings increased twenty-fold. Discussions with MEI's compounding experts revealed that the use of uniformly shaped, ultrafine particles made it more difficult to achieve the needed particle-to-particle chain of contact through the thickness of the material, i.e. increased resistance. The smaller particle size also increased the available surface area at which pores could and did develop. All contract work was performed using particles roughly 3-5 microns in diameter. Use

of the estimated 10-20 micron optimum particle would have required an entirely different production method. Time and associated costs of the changeover were far beyond the scope of this program.

Subsequent electrical testing of the MEI material showed the doped oxide to lack stability at negative electrode potentials. This finding required doped oxide be used as a laminate in conjunction with a material better able to withstand the environment at the negative plate. Carbon black was immediately proposed as the ideal partner, having been previously identified as highly conductive, lightweight, readily available and stable at negative potentials during the first WPAFB contract. Compounding trials optimized the loading, resulting in highly conductive parts that were also very flexible.

Compounding descriptions and the corresponding conductivity measurements are provided as figures in the text.

3.3.2 Subtask 3.2 Substrate Fabrication Techniques

Given the limited batch size and trial-to-trial variability in hand compounding plastic and filler, resins were carefully chosen for study. These included low-density polyethylene (LDPE), fluoropolymer formulations (Kynar), polytetrafluoroethylene (PTFE), and high-density polyethylene (HDPE).

Given its use in prior WPAFB-sponsored work, initial efforts focused on LDPE and Microthene™ from Quantum Chemical Corporation was purchased. A powdered form was requested and received to facilitate uniform filler dispersion with minimum porosity. Dry mixing of the filler and resin was accomplished by hand using a mortar-and-pestle early on in the contract. This was later replaced by V-blending. The mixture was then melt blended in a twin screw extruder to produce pellets that were compression molded into sheet form. Early samples were thick (0.070") and used exclusively for proving the stability of the filler. After several successful resistivity tests, work was redirected on thinning the part and making it more conductive.

Another resin, PTFE, was investigated concurrently. Loadings from 70-75% produced highly conductive parts, however, these were also very porous. Investigations were undertaken with Imprex, Inc. to impregnate the porous parts under vacuum with a polycarbonate-based liquid resin to reduce the porosity without hindering the conductivity. PTFE development was stopped when samples were shown to have remained porous and become even more resistive following treatment.

Kynar was also explored for use as a base resin. The material showed initial promise, during producing conductive and nonporous material during hand compounding trials. However, the 375°C temperature needed to soften and melt the resin degraded the doped oxide. LDPE and Kynar blends resulted in conductive but highly porous material. Development in this area was discontinued given the successes with LDPE.

Additives were next employed to improve the physical properties of the substrate. Coupling agents, oils, acids, acetates and silicon compounds were each investigated in an attempt to improve part conductivity, reduce porosity, and/or improve manufacturing. Coupling agents, designed to bond the filler and surrounding base resin, offered the only quantifiable advantage. Of particular note was a coupling agent available through Kenrich Chemical, Incorporated. Additions substantially improved the resultant substrate's physical properties. Order of addition was also found critical to the end product. Greatest effectiveness was had in dry mixing with doped oxide prior to adding LDPE powdered resin.

Lastly, JCBGI investigated HDPE resin in an effort to widen the operating temperature range of the battery. Initial stability tests showed high porosity levels. Increasing the melt blend temperature produced stable parts. Development was halted in June 1994 when the program's technical direction was changed (see Section 4.0 - Metallic Substrate Development).

Alternative methods of producing sheet stock were also investigated. Molded Rubber and Plastics (MRP) and JCBGI teamed to design a vacuum compression mold to remove trapped gases and produce pore free parts. Unfortunately, samples exhibited physical properties no better than parts made in the conventional manner. Work was discontinued due to the prohibitive \$75/part cost and the large volume of material needed per trial (10+ pounds).

Skiving was no more successful. Thin rolls of doped oxide in Microthene™ were received from DeWal Industries in May 1993 for laminating and resistivity testing. Resultant laminates were 0.029-0.031" thick with resistivities in the range of 1.7-2.0 Ω-cm. Given the promise of the materials produced by DeWal's skiving process, JCBGI twice supplied additional compounded materials for processing into sheet. Doped oxide samples exhibited low initial porosities that increased as a result of the laminating process; the porosity of the carbon black material was never acceptable. Work with DeWal was subsequently discontinued.

Carbon-black development proceeded more quickly with the aid of JCBGI's zinc-bromine battery development program. Several different types of carbon-black were screened and a Ketjenblack material from Azko Chemical was chosen. Compounding trials identified an optimum carbon-black loading level that afforded parts with a conductivity of 1-1.6 ½-cm and enough flexibility to be used as a bipolar substrate.

Laminating the filled LDPE substrates was next addressed. Early laminates exhibited a resistivity higher than the sum of the constituent pieces due to the "skin" formed on the surface of each sheet when molded. Two methods of removing the "skin" were tried. The addition of carbon black at the interface prior to laminating proved effective, but difficult to perform in a uniform manner. The second and adopted method required gentle sanding of the skinned surfaces with sandpaper. Sanding prior to lamination resulted in a 50-75% reduction in part resistivity and no effect on part stability.

3.3.3 Subtask 3.3 Stability Testing

The procedure and fixture for quantifying a bipolar substrate's stability in acid and under potential were developed at JCBGI over many years. Both three- and four-point tests were required to evaluate a sample's viability.

As shown in Figure 15, a substrate sample was clamped between two hollowed polycarbonate endblocks, exposed to electrolyte, and wired as the working electrode. A potential of 1.5 volts was applied and the current collected at the top of the substrate in the three-point system. After 24 hours on test to establish a baseline current, the leads were rearranged to collect current after passing through the substrate, i.e., the four-point test. The test continued for a minimum of 3 additional days. No change in the current acceptance established the sample to be nonporous. A rising current suggested porosity or filler instability. Detailed stability results are provided in Appendix B.

Conductivity before and after the three- and four-point regimen was also monitored. An increase of 20% or more signalled porosity or filler instability. Since doped oxide had been successfully tested, an increase in resistivity was interpreted as increasing porosity, i.e., carbon-black was exposed to the positive potential as a result of the porosity causing the carbon-black to oxidize and become nonconductive.

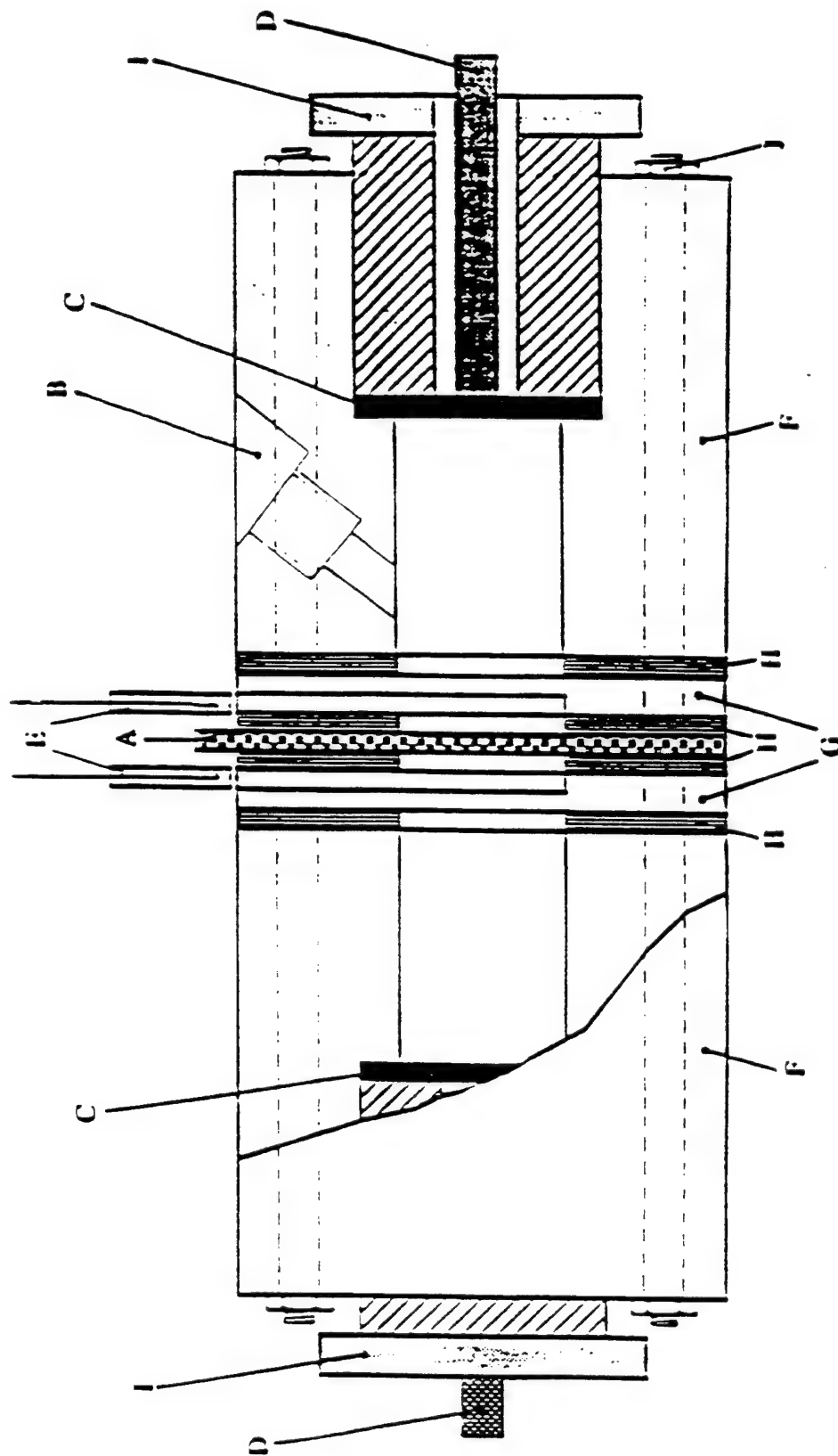
3.3.4 Subtask 3.4 Proof of Concept Testing

Over 60 batteries of various voltages were assembled and tested. Dry, unformed electrodes with 10 in² active areas were alternately stacked with elastomeric spacers and compressed to dimension between 0.5" thick polycarbonate end plates. Insulated bolts positioned around the perimeter of the fixture were easily tightened to compress the gaskets to affect hermetic cell seals. Absorptive glass mat separator was placed between opposing electrodes and filled with electrolyte through channels machined across the upper portion of each

FIGURE 15

Stability Test Fixture

- | | |
|-------------------------------|------------------------------|
| A. Bipolar Substrate | F. Lexan Block |
| B. Reference Electrode Socket | G. Spacer with Sensor Socket |
| C. Counter Electrode | H. Gasket |
| D. Current Collector | I. Counter Electrode Bushing |
| E. Resistance Sensor | J. Clamping Hardware |



gasket. Discharge performance routinely surpassed 5 minutes at 1 A/in², but with limited cycle life.

Laminate and positive paste adhesion were the ultimate issues and numerous approaches were investigated in attempts to foster them. Techniques included roughening the pasted surface with various grit sandpaper, embedding fibers, sintering lead dust or oxide powder onto the active areas, flame spraying lead, pretreating the plastic to increase its wettability. A review of the battery build sequence, documented in Figure 16, quickly shows that any battery formed without the use of lead sheet could not be tested due to high internal resistances caused by poor paste adhesion.

The major breakthrough occurred upon recognizing the special needs of polyolefins. Involved surface pretreatments are recognized as necessary to achieve bonds with wax-like surfaces that are difficult to wet if left alone. Surface treating LDPE prior to attaching a layer of thin lead foil decreased the part resistivity by 50-75%. Over 150 cycles were demonstrated with shorting as the cause of failure. Subsequent builds neared this benchmark, however, lead foil delamination became a recurring problem. Substrate conductivities checked prior to pasting and after cycling showing no change added to the confusion. Treatment parameters were reviewed and found incorrect, resulting in delamination *within* the plastic part. Optimization trials were initiated, along with investigations of HDPE resin. HDPE was proven to bond more strongly to lead sheet, but the resulting cycle life was still unacceptable. Efforts were halted with the change in the program's technical direction.

3.4 WBS 5.0 BATTERY FABRICATION

3.4.1 Subtask 5.1 Sealing Methods

Two 10-volt batteries were produced using an injection molded containment method in October 1993. Electrodes, separators and spacer frames were arranged to form a stack that was inserted into a cavity for molding. Plastic injected into the mold formed a frame around the entire stack to provide the necessary sealing and spacing requirements, as well as provisions for acid fill.

Electrode quality within each 10-volt stack was poor due to the required part size. Length and width exceeded the working area of the press. Pieces were 0.080" thick and highly resistive (10 Ω -cm). Cross sectioning of one dry, unformed (DUF) stack showed complete plastic fill and no electrode distortion. Confirmation of hermetic cell-to-cell sealing was never

FIGURE 16
Composite Battery Builds

ID	Volts	Adhesion Method	Cycles	Cause of Failure
159	4	Lead dust	32	Lack of paste adhesion
159-B	4	Lead dust	15	Lack of paste adhesion
160	4	Lead dust	15	Lack of paste adhesion
182-1	4	Lead dust	5	PbSO ₄ at surface
182-2	4	Sanded surface	5	Lack of paste adhesion
182-3	4	Lead dust	5	PbSO ₄ at surface
182-4	4	Sanded surface	5	Lack of paste adhesion
194-3A	4	Embedded 0.003" glass mat	0	PbSO ₄ at surface
194-4A	4	Embedded 0.003" glass mat	0	PbSO ₄ at surface
194-3A	4	Finely sanded surface	0	PbSO ₄ at surface
194-4A	4	Finely sanded surface	0	PbSO ₄ at surface
205-1	4	0.001" perforated lead foil	18	Lack of paste adhesion
205-2	4	0.001" perforated lead foil	18	Lack of paste adhesion
205-3	4	0.001" lead foil	19	Lack of paste adhesion
205-4	4	0.001" lead foil	14	Lack of paste adhesion
214-1	4	0.010" lead foil over treated surface	18	Leak, cracked substrate
214-4	4	0.010" lead foil	21	Lead foil delamination
214-5	4	0.010" lead foil	45	One very dry cell
214-6V	6	0.010" lead foil over treated surface	47	Lead foil delamination
218-1	4	Carbide fibers	2	Too resistive to cycle
218-2	4	Carbide fibers	2	Too resistive to cycle
224-4	4	0.010" lead foil over treated surface	151	Shed PAM, shorting
224-5	4	0.010" lead foil over treated surface	104	Lead foil delamination
241-2	4	Flame sprayed lead	0	High IR, no AM adhesion
242	12	0.005" lead foil over treated surface	15	Lead foil delamination
242-4	4	Paste over treated surface	0	High IR, no AM adhesion
243-6V	6	0.005" lead foil over treated surface	12	Lead foil delamination
257	12	0.005" lead foil over treated surface	8	Lead foil delamination
259	12	0.005" lead foil over treated surface	0	Lead foil delamination
260-2	4	0.005" lead foil over treated surface	19	Lead foil delamination
263	6	0.005" lead foil over treated surface	9	Lead foil delamination
265	6	0.005" lead foil over treated surface	4	Crack, leak, delamination
267-1C	4	0.005" lead foil over treated surface	15	Lead foil delamination
267-4P	4	0.005" lead foil over treated surface	135	Local lead foil delamination
267-5P	4	0.005" lead foil over treated surface	13	Local lead foil delamination
267-6VP	6	0.005" lead foil over treated surface	33	Local lead foil delamination
267-6P	4	0.005" lead foil over treated surface	18	Local lead foil delamination
267-8C	4	0.005" lead foil over treated surface	20	Local lead foil delamination
267-9P	4	0.005" lead foil over treated surface	20	Local lead foil delamination
267-11C	6	0.005" lead foil over treated surface	11	Local lead foil delamination
268-6VC	6	0.005" lead foil over treated surface	11	Local lead foil delamination
268-8C	4	0.005" lead foil over treated surface	9	Local lead foil delamination
268-10C	4	0.005" lead foil over treated surface	68	Local lead foil delamination
268-11C	4	0.005" lead foil over treated surface	135	Local lead foil delamination
268-12C	12	0.005" lead foil over treated surface	15	Lead foil delamination
277-1C	4	0.005" lead, treated surface, acid dip	2	Local lead foil delamination
277-2C	4	0.005" lead, treated surface, acid dip	4	Local lead foil delamination
277-6VC	6	0.005" lead, treated surface, acid dip	3	Local lead foil delamination
278-1C	4	0.005" lead, treated surface, acid dip	8	Local lead foil delamination
281-1	4	0.005" lead on HDPE, treated surface	6	Local lead foil delamination
282-1	4	0.005" lead on HDPE, sanded, treated surface	23	Lead foil delamination
282-2	4	0.005" lead on HDPE, sanded, treated surface	5	Lead foil delamination
282-6V	6	0.005" lead on HDPE, sanded, treated surface	5	Lead foil delamination
285-1	4	0.005" lead, washed oxide, treated surface	11	Lead foil delamination
286-2	4	0.005" lead, unwashed oxide	0	Short
286-3	4	0.005" lead, unwashed oxide	11	Lead foil delamination
287-2	4	0.005" lead on HDPE, washed, treated surface	1	Cracked substrate
287-3	4	0.005" lead on HDPE, treated surface	10	Lead foil delamination
287-4	4	0.005" lead on HDPE, treated surface	6	Cracked substrate

obtained due to difficulties porting the cells for pressurization tests. The trial did, however, prove that injection molded containment was a viable manufacturing technique.

4.0. METALLIC SUBSTRATE DEVELOPMENT

4.1 WBS 1.0 PROGRAM MANAGEMENT

4.1.1 Subtask 1.1 Managing Strategy

Effective July 28, 1994, Ms. Jennifer Rose assumed the responsibilities of the contract's previous project engineer, Mr. Doug Pierce, due to his departure from JCBGI.

Shortly thereafter, a proposal requesting a no-cost time extension was submitted to the contract negotiator on July 13, 1994. Gantt charts detailing this effort are shown in Figures 17 and 18. This followed a discussion with Mr. Richard Marsh during which it was mutually agreed that, despite significant advances in composite bipolar substrate development, remaining WPAFB contract work should be focussed on the use of a lead substrate with improved corrosion resistance. Through a parallel bipolar program, JCBGI had repeatedly demonstrated 2000+ cycles in a 12-volt configuration utilizing lead substrates, and over 5700 cycles using a 6-volt unit. Laminated metallic substrate work had also been underway for nearly 12 months in an effort to increase corrosion resistance, and hence, cycle life.

4.2 WBS 2.0 BATTERY DESIGN

4.2.1 Subtask 2.1 Battery System Design Analysis

The existing small metallic bipolar battery design was scaled up and modeled to investigate high power performance. Results suggested the use of a thinner cell design to be critical to achieving rates of 500 W/kg and higher. Per these findings, work was redirected to designing a 24-volt module within the volume previously allotted for 12-volts. This effectively aligned the contract deliverable voltage with WPAFB's ultimate application and JCBGI's commercial product target. Constant power performance projections are shown in Figure 19.

4.3 WBS 3.0 BIPOLAR PLATE

4.3.1 Subtask 3.1 Multialloy Substrate Development

Under separate contract, JCBGI began investigations into laminated metal substrates in November 1993. Corrosion testing of three, four and five layer samples and constituent alloys was performed in a bipolar configuration to assess time to breakthrough. Unpasted samples were mounted in the previously described stability test fixtures (Composite Substrate Work, Subtask 3.3) for three-point testing. Only the positive surface was exposed to electrolyte. Working and reference electrodes were also introduced. Initial testing of a new material was

FIGURE 17: No-Cost Time Extension Gantt Chart with Milestones

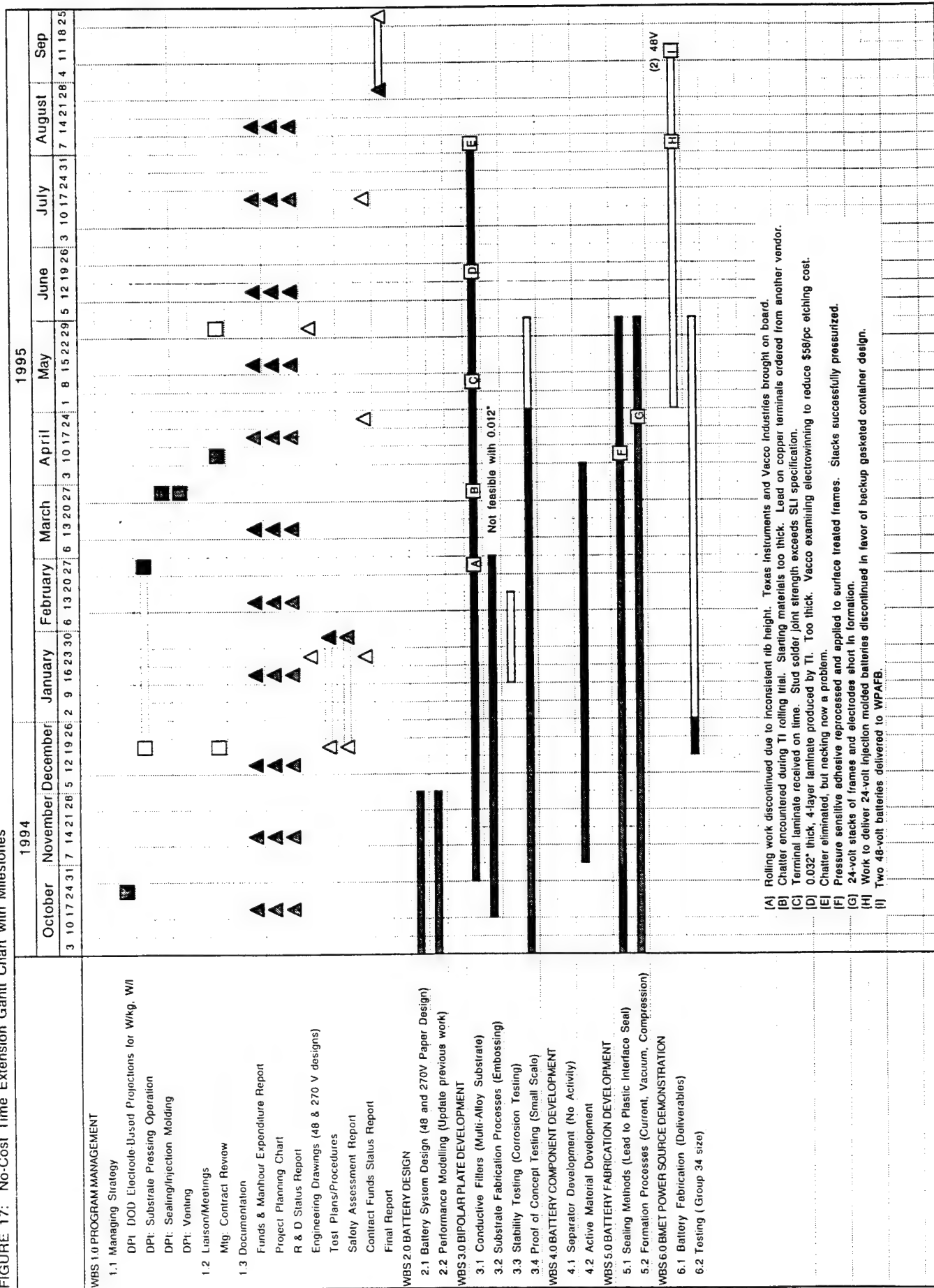


FIGURE 18: WPAFB Bipolar Deliverable Schedule

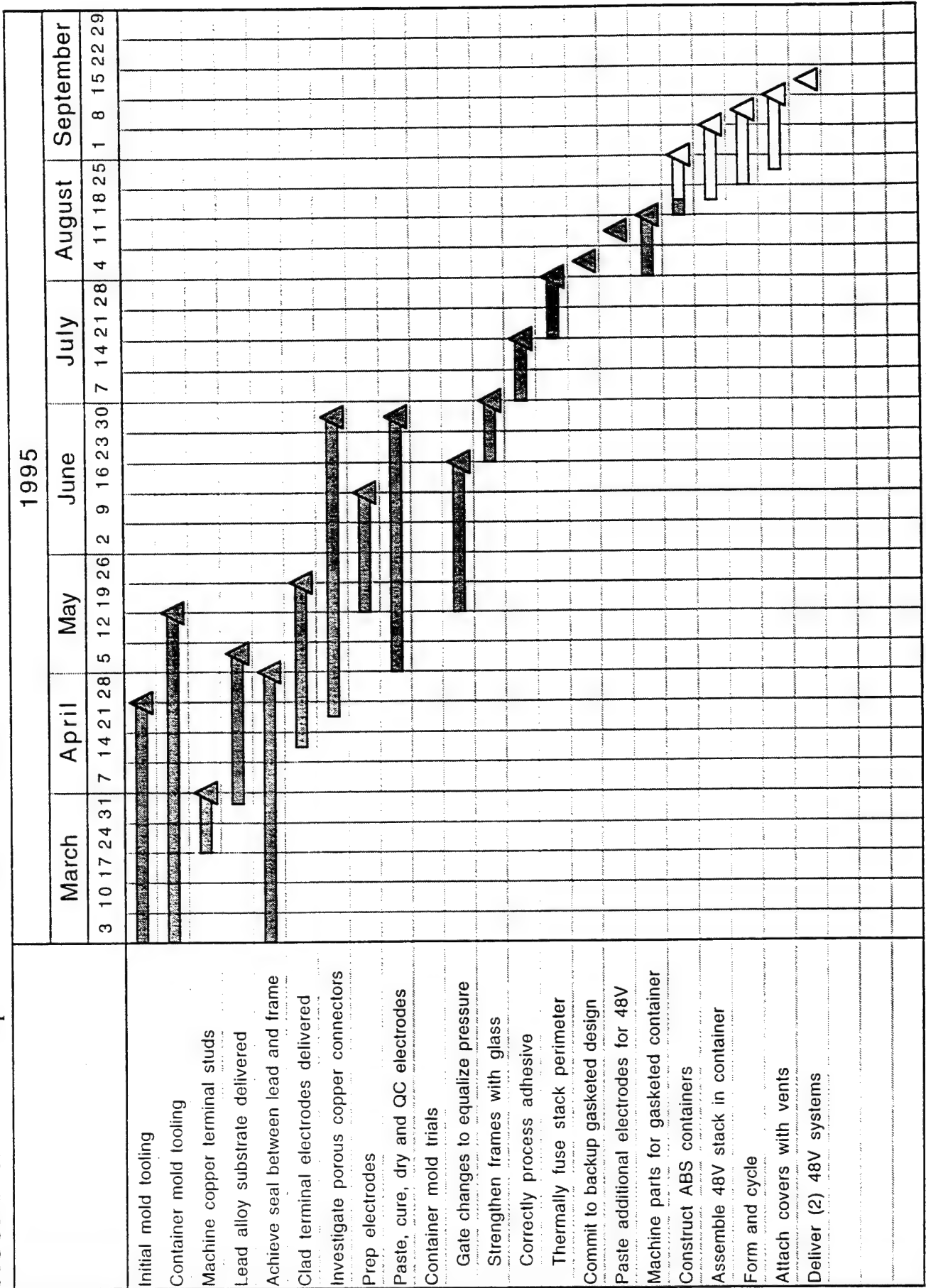
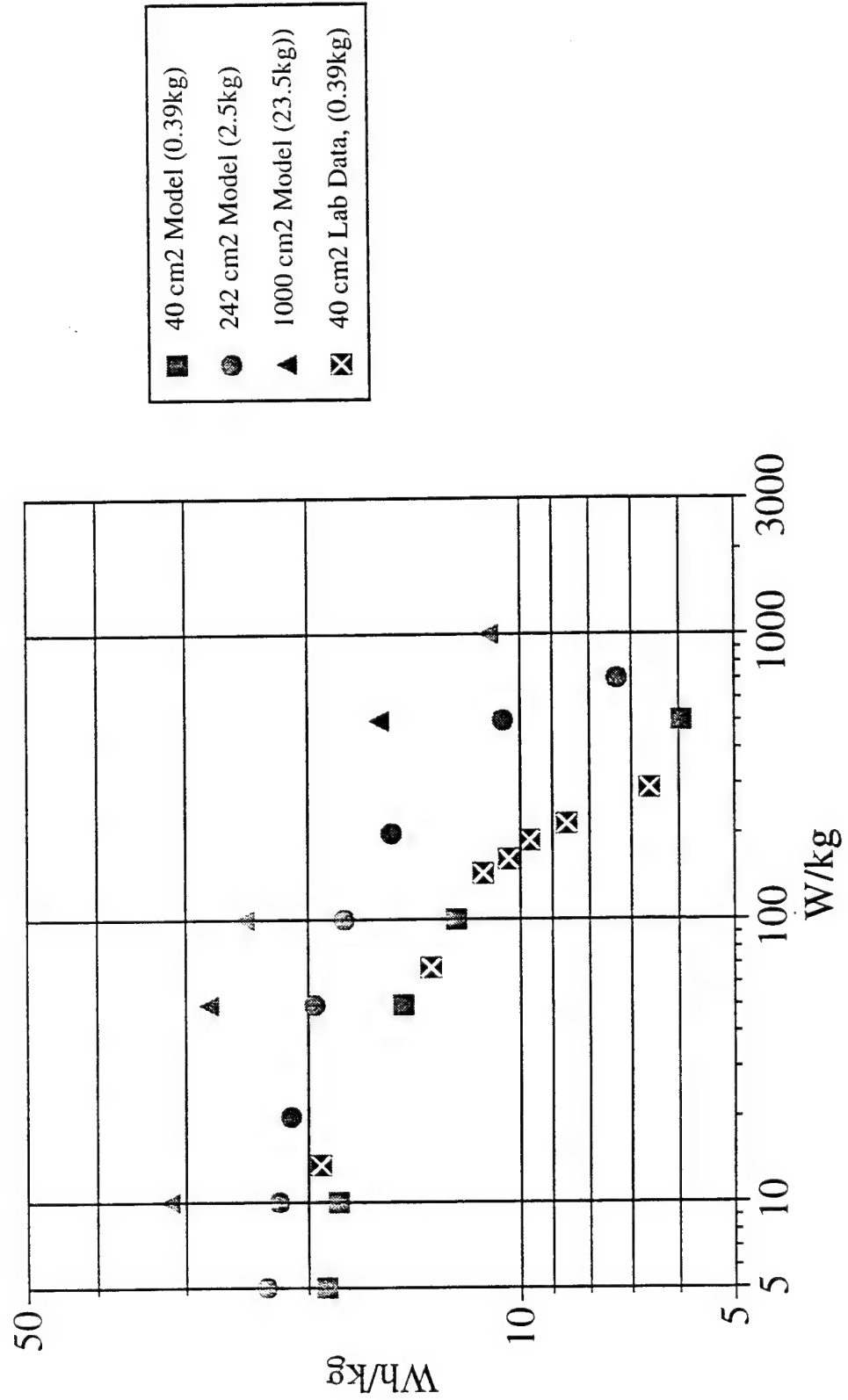


FIGURE 19
Constant Power Performance Projections
Metallic Bipolar Substrate



performed at 70°C and a constant potential of 1.50 V until evidence of pinholes was noted, i.e., liquid in the back chamber or spikes on the current acceptance curve. Replicate samples were then run, pulled at points prior to breakthrough, and submitted for cross sectional photomicrographs to quantify the corrosion rate.

Comparing rates of all samples tested showed the corrosion resistance of laminates to be second only to that of a high silver content alloy. Batteries utilizing the clad material were assembled and tested, but performance was poor. Teardowns showed improper cleaning of the starting materials to have prevented bonding of the dissimilar metals at the molecular level. Delamination resulted in high internal resistance that impeded high rate performance.

In October 1994, assistance was sought from Texas Instruments' Cladding Division (TICD), a leader in the laminating industry. Partnership activities were slow to materialize due to reorganization within TICD, however, two- and three-layer trials cladding lead to a stainless steel core were successful in December 1994. In March 1995, lead clad copper material was received and forwarded to Vacco Industries (see Metallic Substrate Work, Subtask 3.2) for surface etching trials. TI had planned bonding and rolling to facilitate a 65% reduction of the 0.054" thick constituent layers, however, a maximum of 51% was achieved before "chattering" (rippling) was observed. Secondary rolling ruined the bonds achieved in the first pass. New starting materials were requested for the production of 0.013" thick material, but the May delivery date made it unlikely that the laminated material would be available for use as the bipolar substrate in the required deliverables. Four layered, 0.032" thick sample material was received in June, and required reducing the copper core thickness by 50%. The likelihood of having the concept ready for deliverable use then dismissed.

4.3.2 Subtask 3.2 Rolling/Embossing Work

Fostering paste adhesion to metal sheet requires the surface to be roughened in some manner. Small-scale metallic substrates possessed exemplary adhesion when hot pressed in a mold to create ribs protruding from each face. The raised pattern successfully broke up the "single paste pellet" that would otherwise sheet off the lead substrate during handling, and increased the surface area biting into the active material.

Substrate production times were slow and scale up required the use of more tonnage than available on any in-house press. It also lacked promise as a high speed, manufacturing process. A roller die was ordered and five hundred pounds of 0.020", 0.025" and 0.030" thick lead were delivered to MP Metal Products for rolling trials. Without authorization, MP turned to blanking the electrodes from a compression die when the first rolling trial was unsuccessful. Rolled

samples were never provided to JCBGI for evaluation. When informed of the new production direction, JCBGI reiterated their interest in the rolled concept, but conceded to whatever parts could be produced. Time was short. MP continued their effort to produce parts, but quickly found their press tonnage insufficient. Hence, a new vendor was located. Walking 300 tons force across the die produced acceptable parts from 0.020" thick starting material. Efforts to reduce the substrate thickness to the required 0.012" thickness were unsuccessful and the embossing effort abandoned.

Photochemical etching was investigated in conjunction with laminating activities (Metallic Development Work: Subtask 3.3.1). Early trials produced copper pieces that were electroplated with lead, pasted and shown to possess good adhesion. Solid lead sheet was not etched as easily, requiring strong chemicals that made the technique cost prohibitive (\$58/piece).

As backup, plastic screen was used. Pieces were cut to the size of the active material area, pressed to eliminate elevated nodes that could cause shorting through the separator, and were tacked to the lead substrate. This alternative eliminated roughly 240 grams of lead rib mass per battery, but required significantly more labor input than the embossing concept. Despite its facilitating acceptable results, the use of plastic screen is not recommended for manufacturing.

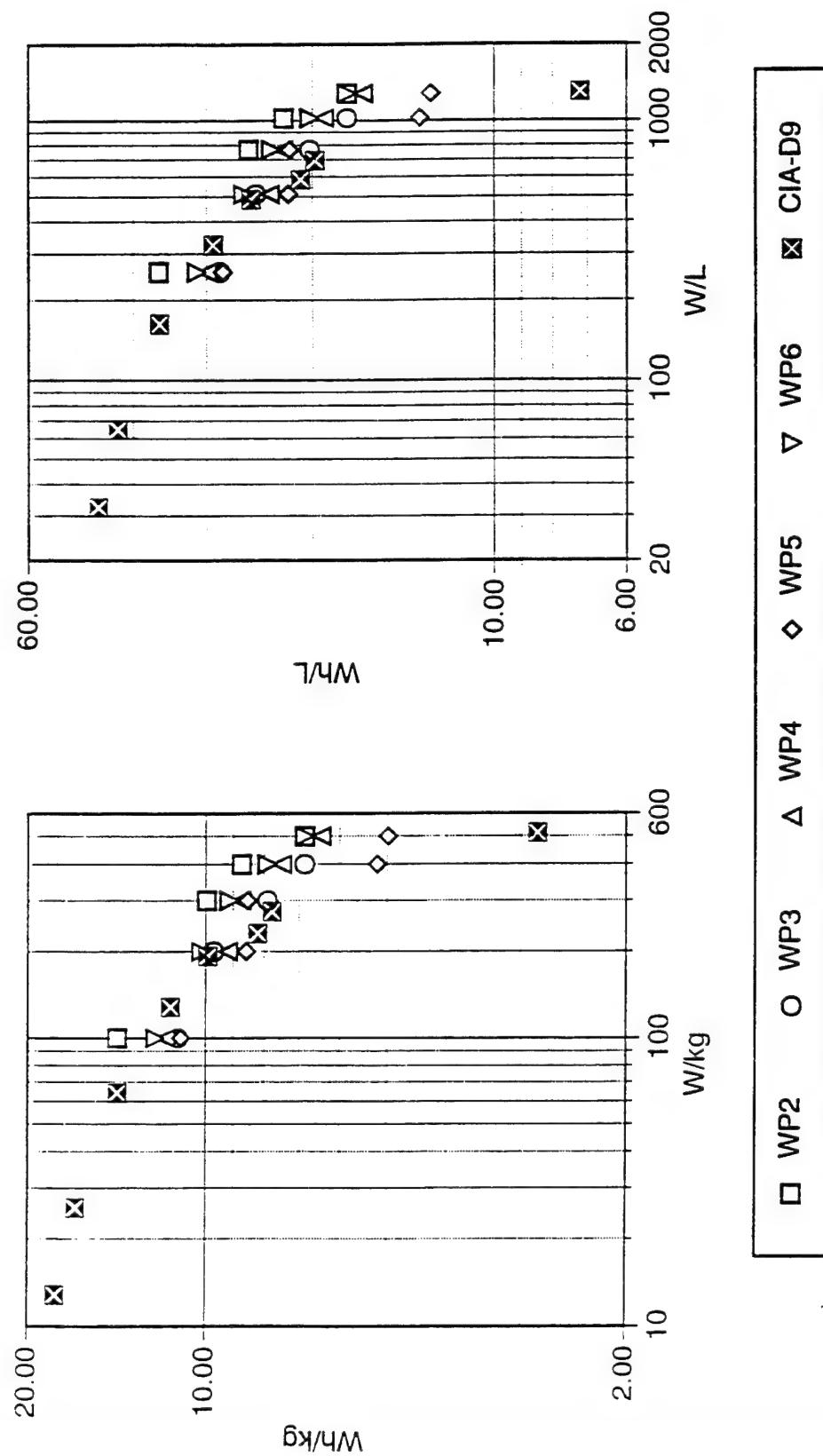
4.3.3 Subtask 3.3 Substrate Corrosion Testing

Laminates received from Texas Instruments were never corrosion tested due to their being too thick.

4.3.4 Subtask 3.4 Small Scale Characterization

Bipolar batteries having 0.012" thick substrates and 0.030" thick pasted layers were assembled, formed and tested in January 1995. Constant power discharge performance plots normalized to battery mass and volume are shown in Figure 20. Performance by WP2 and WP6 represented the best of the lot and greatly exceeded that reported for batteries delivered under the parallel metallic bipolar development contract. This was attributed to the use of 1.265 sg fill/form electrolyte. Reproducibility was an issue and investigated. Teardowns showed sulfated positives and dull negatives. Cured paste analyses reported consistently high levels of free lead that could cause initially poor or rapidly declining performance. A review of pasting procedures showed the starting PbO to be within specification and the paste code to be adequately sulfated

FIGURE 20
Constant Power Performance Normalized to Mass and Volume



and consistent from mix to mix. The dry bulb within the curing chamber was found cracked and was repaired prior to further assembly operations.

Testing of four newly-formed 12-volt units showed 10-15 cycles at 100 W/kg to be necessary to reach full capacity. Discharge times were tightly grouped after formation (Figure 21). WP-12 lagged due to oxygen ingress at cycle 3. A cursory investigation of constant current rates (Figure 22) was performed to give insight into the constant power rates required per the test plan. Constant power performance was plotted along with the modeling prediction in Figure 23, then translated into the time versus power curve shown in Figure 24.

4.4 WBS 4.0 BATTERY COMPONENTS

4.4.1 Subtask 4.2 Active Material Development

Procedures and equipment were reviewed when the free lead content in positive and negative cured plates was reported at 5.5 and 10%, respectively - far above the 4% maximum. Increasing the curing residence time from 16 to 40 hours had little effect. Moisture content was found low (6-7%) as referenced to industry and company standards and, subsequently, paste code and plate handling techniques were reviewed. Efforts to keep plates moist while awaiting transport to the curing chamber only slowed the cure reactions and actually increased the cured free lead content. Lastly, the ABR humidity chamber was diagnosed with a cracked dry bulb, repaired and reset. Cured positive and negative plates from eight subsequent pasting runs displayed acceptable free lead content following a 24 hour residence time in the environmental chamber.

A limited investigation into the effects of freezing and thawing a small 12-volt battery was performed. One unit was tested at room temperature to establish a baseline capacity and then chilled to -60°C. A 5-hour thaw was allowed and the discharge test repeated. Evidence of cell reversal and a 13% capacity loss was documented. Confirmatory work was placed on hold to allow pasting, stacking and debugging of the formation techniques proposed for full-size, 24-volt units.

4.5 WBS 5.0 BATTERY FABRICATION

4.5.1 Subtask 5.1 Sealing Methods

A variety of compounds was evaluated for use in achieving a hermetic cell-to-cell seal. In the end, an engineering sample of hot melt adhesive was pressed between release paper into

FIGURE 21
Small Scale Characterization
Capacity Development, 24 deg C

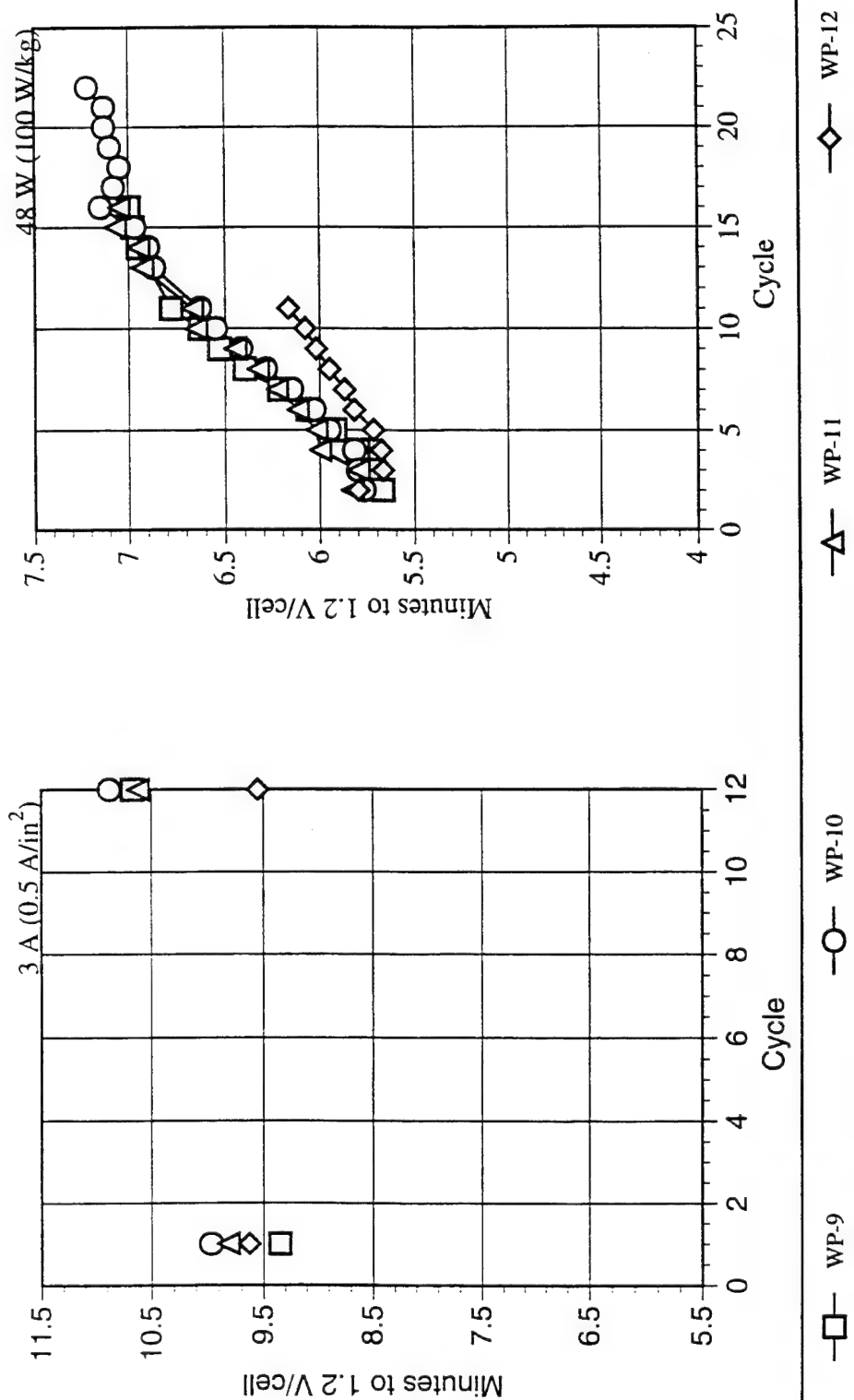


FIGURE 22

Small Scale Characterization
Peukert Relationship, 24 deg C

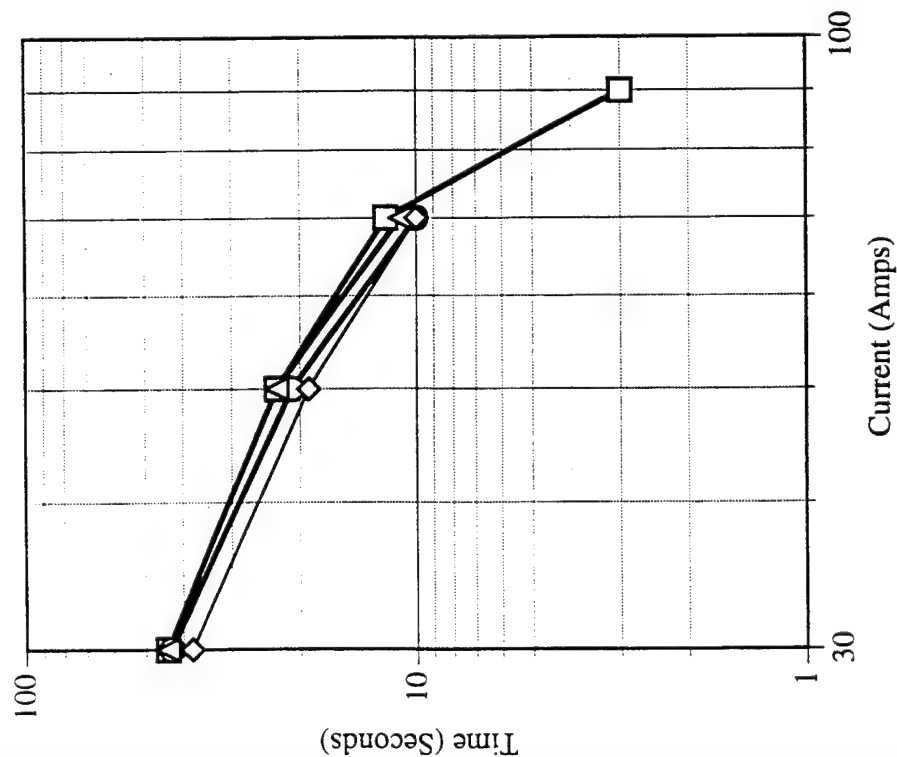
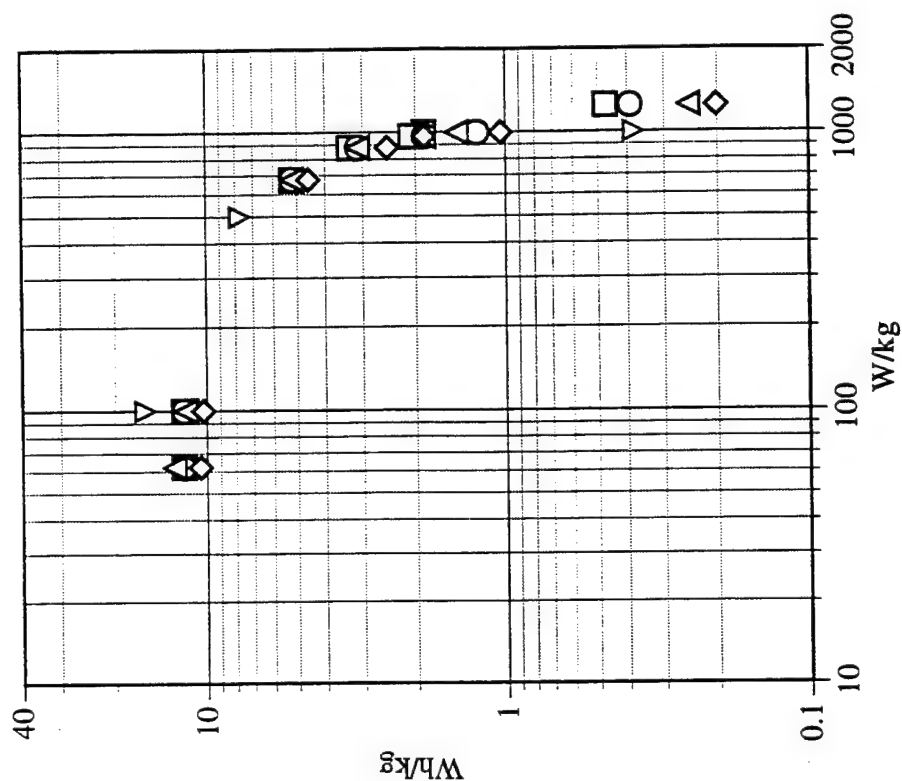


FIGURE 23

Small Scale Characterization
Ragone Relationship, 24 deg C



Model

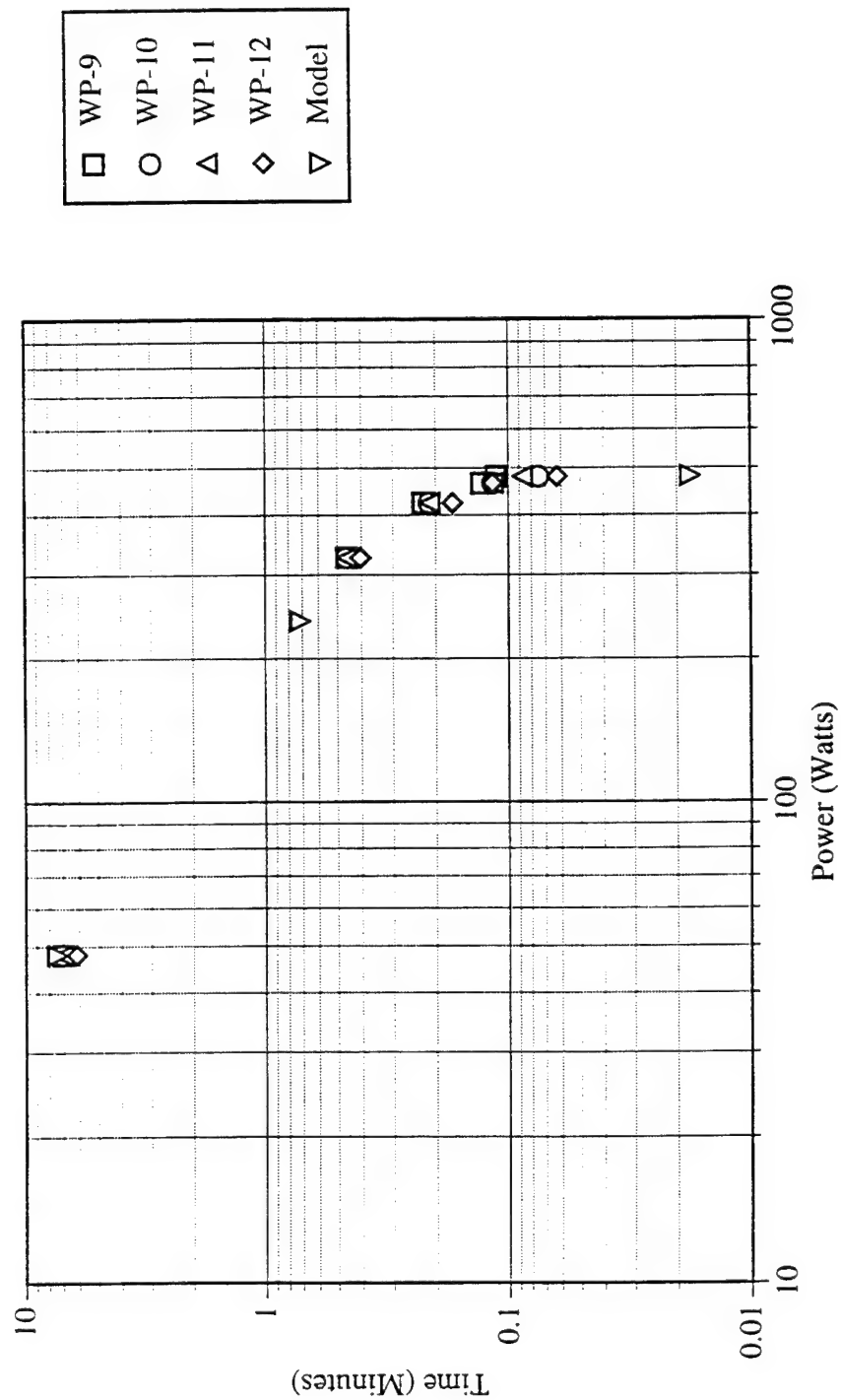
WP-12

WP-11

WP-10

WP-9

FIGURE 24
Small Scale Characterization
Discharge Time vs Power, 24 deg C



sheet, chilled, slit into ribbon, chilled again, and finally laid onto treated plastic spacer frames. Dummy stacks were leak-free to 4 psig, and successfully completed 4 hours of intermittent vacuum pulsing to simulate the fill and form procedure. Cells in 12- and 24-volt stacks were also leak-free when similarly tested.

Sufficient quantities of the engineering sample material resided in-house, but efforts to find a replacement adhesive were initiated when additional material could no longer be obtained. Chemical analyses and physical testing of the original material was requested of H.B. Fuller and resulted in their furnishing two candidate replacement materials. Stack assembly showed one sample to be tackier and both materials able to withstand the level of vacuum required for filling. No further work with these substitutes was carried out since sufficient adhesive existed to complete the contract.

4.5.2 Subtask 5.2 Formation

Two 24-volt batteries were stacked for formation studies. Each was comprised of 13 electrodes, 12 spacer frames, and two copper termination plates bolted between polycarbonate endwalls and outfitted with polycarbonate filling manifolds across each set of top slots.

Air pressurization of the first stack prior to filling showed one of the two fill ports to be leaking. The manifold was removed and the slots closed off after repeated attempts to seal the manifold were unsuccessful. Seventy-five minutes were required to input 300 cc of chilled electrolyte through the remaining manifold. This represented roughly 72% of the available void volume in the stack. Complete (100%) saturation had been targeted, however, small leaks developed around the base of the manifold, decreasing the fill efficiency. Current was applied for 120 minutes when evidence of shorting was apparent. Disassembly showed the majority of cells to have dendritic shorting through the center area of the separator. Failure was attributed to the long fill time (10-15 minutes was targeted to minimize the dissolution and diffusion of lead into the separator) and out-of-spec plate thicknesses. On average, plates were 0.007" over the 0.025" target, resulting in a compressed separator allowance of 0.016". Roughly 0.020" was considered the minimum separator thickness. Paste weights were reduced for the subsequent build.

The second 24-volt battery was assembled into a bolted polycarbonate fixture, filled to 84% saturation with chilled electrolyte, and placed on formation. Further filling risked lead dissolution and dendrite formation in the separator due to the excessive time required. Five cells shorted during formation as a result of a common electrolyte path along the lead exposed within the fill channel. Further formation attempts were placed on hold pending receipt of a molded stack which, by design, better guarded against common electrolyte paths in the fill port area.

4.6 WBS 6.0 BMET DEMONSTRATION

4.6.1 Subtask 6.1 Deliverables

Injection molded containment about metallic substrates was aggressively pursued for the majority of the No-Cost Time Extension. Repeated trials ultimately succeeded in correcting recurrent frame and electrode distortion, however, hermetic cell-to-cell seals were not obtained. Stacks were never available for formation or for trials to attach covers via induction welding. As a result, a backup battery design was implemented to complete the contract's deliverable requirements.

The following section describes the injection molded containment work in more detail, along with the proposed venting and intermodule connector concepts. The subtask is then concluded with a description of the batteries delivered to WPAFB.

4.6.1.2 24-Volt Injection Molded Containment

The use of the injection molded containment concept previously tested with composite electrodes required one design modification to facilitate use with metallic substrates. To prevent distortion of the 0.012" thick metal electrode, the outer edge of the spacer frame was reshaped to wrap around the lead sheet and afford protection against the injection pressure. Glass filler was also added to the spacer resin to promote a melt bond with the outer endwalls. Molded spacers showed that shrinkage of the 0.082" thick parts was less than anticipated (0.003 in/in vs. 0.007 in/in). This was due to the ASTM shrinkage rate reporting basis (0.125"x0.5"x6" sample). As a result, spacers were slightly larger than specified, however, down-the-line assembly problems were not encountered.

The endwall material was also reevaluated and three candidates tested for use in maintaining the compressed stack dimension. Single layers of honeycombed aluminum sheet stock failed deflection testing. Bulk molding compound manufactured by Luvdahl provided the needed strength against a 6 psig load but was incompatible with battery acid. Glass-filled polypropylene was ultimately used after measuring a deflection of 0.013" at 5 psig.

Severely warped endwalls were produced during the first mold trial. Mold gate changes reduced the distortion, but a subsequent heat soak was still necessary to produce a flat part. Limited success was had in adding a blowing agent. Topical sinks located around the outer perimeter and the center termination port were greatly reduced but not eliminated. Slight part warpage also remained. Cross sectioning showed the internal pore size (caused by the blowing agent) to be very small. It also showed a 4-hour heat treatment to cure the warpage with no sign

of reactivating the blowing agent, but at the expense of the recessed terminal electrode cavity dimension. Heat treating was abandoned when measurements showed shrinkage along the length and width centerlines to be so great as to make it impossible to insert the terminal electrode in the recessed cavity.

Endwalls and spacers were then assembled with lead sheet to create dummy stacks for mold trials. Early attempts showed the plastic to distort the 10% glass frames inward toward the pasted portion of the stack, leaving insufficient material to fill the outer frame. Gate modifications were implemented in an effort to equalize the injection pressures at various points within the container mold. Center/side gating achieved complete mold fill and eliminated much of the frame distortion, however, cross-sectioning still showed buckled lead and uneven plastic distribution. The mold clamp location was then widened and additional glass added to the spacer resin for strength.

Strengthened plastic battery components were received and set up parts prepared for a trial in mid-July, 1995. Glass loading in the frame was increased to 30% in order to prevent blowing in and lead distortion, and to reduce part compression when clamped within the mold. The molding trial was nearly successful. Complete mold fill was achieved with slight crowning of the frames. A "clamp only" trial showed the crowning to be a result of the mold closing. Still closer examination revealed the stacks loaded into the mold to be ~0.100" too thick as a result of out-of-spec adhesive. The remaining thick stacks were preheated and easily compressed to the correct 1.454" thick dimension. Disassembly showed no electrode distortion. Laboratory measurements of stacks assembled using 0.003" thick adhesive (a 50% reduction) were similarly flat.

The subsequent molding trial with correctly processed adhesive produced four dummy stacks and one DUF battery for analysis. Electrodes in all four dummy stacks were distorted along the inner frame perimeter. Heat sensitive indicators inserted at two points in each stack recorded the temperature history and showed no indication of having reached the temperature at which the inlaid adhesive would begin to flow.

The distortion was subsequently eliminated in late July by thermally fusing the outer edges of the stack to better resist the high molding pressure. Pressure testing to confirm cell-to-cell seals identified leakage that was traced to the area surrounding the fill channels. Close examination showed a lack of melt bond between the prefused frame and injected containment plastic. Given the cost and time associated with the mold change proposed to eliminate the leakage, the concept was abandoned for use with WPAFB deliverables.

Venting considerations were evaluated concurrently to stack molding. Implementation of a totally sealed design was initially considered, but dismissed. Utilizing a fail-safe panel along

the face representing the endwall would have reduced its functionality as a means of maintaining adequate battery compression. User safety in the event of an abusive overcharge was an even greater concern.

A review of available off-the-shelf vents quickly showed that no battery vent supplier had ever addressed the main issue facing bipolar technology: cell width. Vent designs just 0.060" to 0.080" in width did not exist. Staggering the vents was proposed, but eliminated from further consideration when it became apparent that multiple frame molds would be required.

Having limited data showing success in cycling a small bipolar battery utilizing single point venting, the deliverable venting configuration was drawn. In its final form, a 24-volt battery was to be fitted with a vent over each of the fill slot locations. This duplicity provided a backup venting location to any cell that might incur blockage in one of its ports. Oil applied topically aided in achieving and maintaining the hermetic seal required for recombinant, maintenance-free operation.

Two methods were suggested for attaching the vent/cover to the injection molded battery housing: heat sealing and induction welding.

Heat sealing is used throughout the battery industry. Generally, this involves heating the edges to be joined, bringing them into contact, and allowing them to cool under pressure. Concern was raised over being able to hold the 0.080" thick cover while preheating it with a heat lamp. That and the estimated \$30,000 to build a suitable machine to try the concept made heat sealing a last choice technique.

Induction welding was then investigated. This process was reportedly fast and versatile. Heat induced by a high frequency electrodynamic field in a metallic insert placed at the joint brings the surrounding material to the melt temperature. Pressure maintained as the field is turned off maintains the joint as it solidifies. Welding occurs only in the area immediately adjacent to the metallic insert. As a result, weld strength depends on the size and geometry of the metal insert.

The process was also feasible economically. Purchasing a new laboratory unit required \$10,000. Leasing was also possible at \$750 per month.

Initial induction welded samples prepared by Pillar Industries indicated that a hermetic bond could be easily achieved around the periphery of the vent/cover. A semicircular cavity rimming the upper edge of the battery and the two cross bars spanning the center portion of the upper surface was included in the mold design. Later testing proved that a hermetic bond along the cross bars would not be achieved. Mold changes were ordered to reduce the cross bar height to make them serve only as structural supports. Hermetic seals at these points were not necessary given the remainder of the cover weld met specification. Test welds with stacks and covers were never attempted given the difficulties previously described.

Lastly, NCTE work was performed to efficiently connect two 24-volt units in series to form a higher voltage subassembly. Various porous copper samples were obtained and tested under load. Results showed the porous copper to be less resistive than solid copper sheet wrapped around a foam pad (Figure 25). Twenty pieces of 60 pores per inch (ppi) material were ordered and received on time, but never used in deliverables. The batteries delivered utilized a backup containment design that facilitated direct assembly of higher voltage stacks.

4.6.1.3 Gasketed Containment

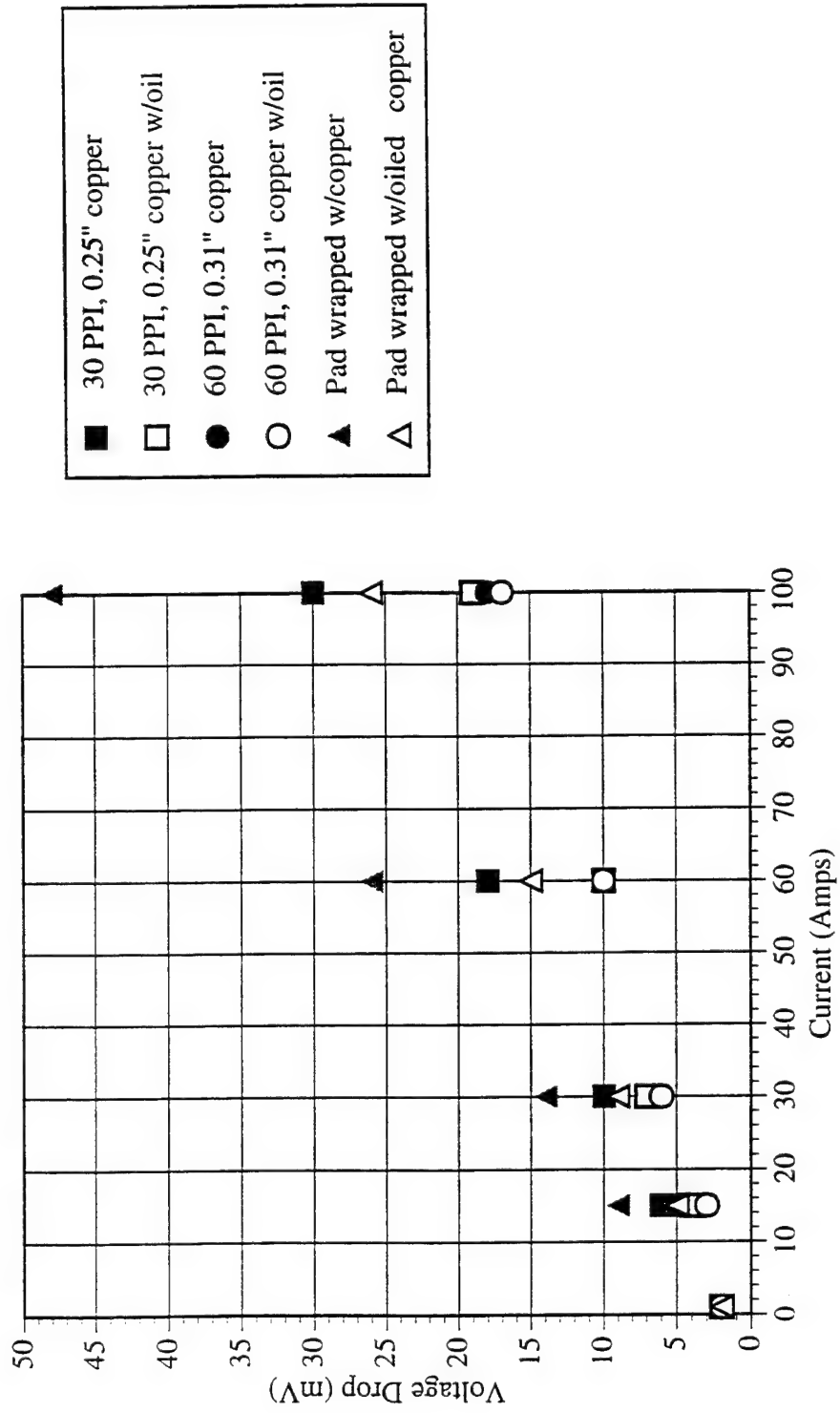
Given the difficulties encountered in achieving hermetic cell-to-cell seals with the injection molded containment concept, WPAFB accepted deliverable batteries assembled using neoprene spacers and machined ABS container components (Appendix B).

Bipolar electrode substrates were die cut from 0.012" thick tin-lead sheet and pasted following the attachment of plastic screen (see Metallic Substrate Development, Subtask 3.3.2). Three paste runs succeeded in pinpointing the wet paste weight needed to achieve the targeted 0.062" electrode thickness. After curing and drying, plates were individually cleaned, weighed, and checked for high spots (thickness). Paste mass and thicknesses of bipolar electrodes used in the deliverable candidates were put at 105.7 ± 2.5 grams and 0.059 ± 0.001 ", respectively.

Terminal electrodes were die cut from laminated sheet stock comprised of 0.008" thick lead and 0.014" thick copper. This design permitted copper terminations to be soldered to the copper face of the electrode with minimal risk of burning a pinhole through the lead face. Each 0.75" long x 0.75"OD stud with a tapped thread was correctly located by first soldering it to an oversized electrode that was then die-cut to achieve the required dead-center location. (This procedure had been critical to injection mold trials since the stack position in the mold was based on the stud location.) Stud welds were shown to withstand an average of 285 in-lb of torque before failing at the solder-to-laminate joint. This compared favorably to the 180 in-lb SLI specification.

Container components were machined from 0.125" and 0.250" (nominal) thick ABS. Solvent bonding was implemented to join the pieces. Endwalls were provided the necessary strength by encapsulating multiple sheets of honeycombed aluminum within a protective ABS cavity. Electrodes were sequentially placed onto neoprene gaskets and absorptive glass mat positioned over the active area to prevent shorting. Separator material was sized to overlap the active area slightly. Starting thickness facilitated the 25% compression deemed critical to supporting high rates of discharge. Fittings were located in channels milled into each gasket to create ports for filling and venting.

FIGURE 25
Voltage Drop Across Intermodule Connector Candidate Materials



Fill and formation were attempted only after confirming each and every cell in a stack to be leak free. Filling was accomplished by evacuating the cells through a column of chilled electrolyte. Returning the system above the electrolyte to atmospheric pressure forced the predetermined volume of acid into each cell quickly and efficiently. Internal stack temperature was monitored constantly and used in controlling the formation current. Current was applied as soon as the fill was completed to minimize the risk of dendritic shorting due to lead dissolution.

Fittings were removed and the cover/vent assembly solvent bonded into place after limited qualification cycling was performed to fully develop the capacity. Details regarding the assembly, formation, and qualification testing of each deliverable are included in Appendix B.

To assist WPAFB in preparing for receipt of these units, three bound copies of safety instructions and operating recommendations were mailed February 29, 1996. One 24-volt and two 12-volt nominal batteries were hand delivered to Wright Laboratory on March 6, 1996 with an additional two copies of the instructions and recommendations. Identification and safety labels were attached to each battery to warn of the potential for explosion, acid burns and electrical shock.

APPENDIX A

RESISTIVITY TESTING

RESISTIVITY TESTING

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
47A	4/2/92	LAMINATED 85% GC23N	0.365	0.023	6.248	0.960	0.042	8.999	36.6158656
		W/O CA	0.450	0.024	7.382	0.640	0.042	5.999	
		15% MICROTHENE	0.270	0.023	4.622	1.060	0.042	9.936	
		4.5 M.I.		6.084				8.311	
48A	4/2/92	C-PLASTIC							7.415184
		LAMINATED 85% GC23N	0.630	0.025	9.921	1.000	0.040	9.843	
		WITH CA	0.570	0.024	9.350	1.500	0.040	14.764	
		15% MICROTHENE	0.635	0.024	10.417	0.740	0.040	7.283	
52	4/9/92	C-PLASTIC							1696.53351
		LAMINATED 84% GC23N	1.180	0.053	8.765	19.500	0.062	123.825	
		& 16%PTFE TO				17.500	0.062	111.125	
		C-PLASTIC & Pb FOIL SINGLE APPLICATION OF RESIN				38.000	0.063	237.470	
53	4/9/92	LAMINATED 84% GC23N	3.630	0.061	23.428	169.000	0.054	1232.138	5273.26123
		& 16%PTFE TO				161.000	0.054	1173.812	
		C-PLASTIC & Pb FOIL				188.000	0.054	1370.662	
		DOUBLE APPLICATION OF RESIN						1258.870	
54B	4/14/92	LAMINATED 85% GC23N-1	0.195	0.040	1.919	0.440	0.040	4.331	138.119658
		15% MICROTHENE				0.483	0.040	4.754	
		4.5 M.I.				0.470	0.040	4.626	
		WITH Pb FOIL						4.570	
55B	4/14/92	LAMINATED 85% GC23N-2	0.250	0.030	3.281	1.730	0.030	22.703	924
		15% MICROTHENE				2.350	0.030	30.840	
		4.5 M.I.				3.600	0.030	47.244	
		W/O pb FOIL						33.596	
71A	4/24/92	LAMINATED	0.295	0.206	0.554	0.390	0.209	0.735	38.0646797
		THICK/THICK	0.300	0.208	0.568	0.430	0.211	0.802	
		GC23N-1 /C-PLASTIC	0.280	0.208	0.530	0.400	0.208	0.757	
					0.554			0.765	
72A	4/24/92	LAMINATED	0.275	0.208	0.521	0.495	0.210	0.928	70.763192
		THIN/THIN	0.265	0.208	0.502	0.410	0.210	0.769	
		GC23N-2 /C-PLASTIC	0.275	0.207	0.523	0.500	0.209	0.942	
					0.515			0.880	
73A	4/24/92	LAMINATED	0.420	0.031	5.334	3.800	0.031	48.260	2063.76933
		THICK/THIN	0.250	0.032	3.076	8.800	0.031	111.760	
		GC23N-3 /C-PLASTIC	0.220	0.033	2.625	6.400	0.032	78.740	
					3.678			79.587	

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
74A	4/24/92	LAMINATED THIN/THIN	0.380	0.380	0.032	0.032	4.675	4.300	4.300	4.300	0.032	0.032	52.904	52.904	1079.12921
		GC23N-4 /C-PLASTIC	0.440	0.430	0.033	0.031	5.249	5.100	5.100	5.500	0.033	0.032	60.845	67.667	
75A	4/24/92	LAMINATED THICK/THIN	0.350	0.280	0.121	0.123	1.139	0.570	0.570	0.570	0.122	0.123	1.839	1.664	15.9055035
		GC23N-5 /C-PLASTIC	0.580	0.280	0.122	0.123	1.872	0.520	0.520	0.320	0.123	0.123	1.024	1.509	
76A	4/24/92	LAMINATED THIN/THICK	0.285	0.275	0.124	0.126	0.905	2.350	2.350	2.580	0.125	0.124	7.402	8.192	780.246688
		GC23N-6 /C-PLASTIC	0.275	0.270	0.126	0.126	0.859	2.580	2.300	2.300	0.124	0.123	7.362	7.652	
77A	5/12/92	LAMINATED GC23N-A-3/92	0.36	0.36	0.026	0.026	5.451								
		Pb-FOIL C-PLASTIC													
78A	6/5/92	LAMINATED GC23N-B-3/92	0.22	0.22	0.026	0.026	3.331								
		Pb-FOIL C-PLASTIC													
78A	6/5/92	LAMINATED GC23N,MICROTHENE & C-PLASTIC	0.66	0.66	0.027	0.027	9.624								
		1R 2R 3R	0.228 0.185 0.21	0.228 0.185 0.21	0.03 0.03 0.027	0.03 0.03 0.027	2.992 2.428 3.062	0.38 5.8 0.66	0.38 5.8 0.66	0.03 0.03 0.028	0.03 0.03 0.028	4.987 76.115 9.280	4.987 76.115 9.280	66.6666667 3035.13514 203.061224	
79A	5/20/92	LAMINATE GC23N-1-85% MICROTHENE/CA	0.52	0.52	0.046	0.046	4.451	3.7	3.7	0.046	0.046	31.667	31.667	611.538462	
		GC23N-2-85% MICROTHENE	0.335	0.335	0.044	0.044	2.997	2.2	2.2	0.044	0.044	19.685	19.685	556.716418	
79A	5/20/92	GC23N-3-80.3% KY	0.49	0.49	0.039	0.039	4.946	21	21	0.041	0.041	201.652	201.652	3976.65505	
		GC23N-4-80.3%	0.435	0.435	0.037	0.037	4.629	13.5	13.5	0.038	0.038	139.867	139.867	2921.77858	

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
80A	5/27/92 PG.139/141	KY/CA							
		LAMINATE							
		GC23N-1-85%	0.36	0.445	0.04	0.04	3.543	4.380	23.6111111
		MICROTHENE/CA							
		GC23N-2-85%	0.495	0.525	0.039	0.038	4.997	5.439	8.85167464
		MICROTHENE							
		GC23N-3-80.3%	0.223	0.253	0.044	0.044	1.995	2.264	13.4529148
		KY							
		GC23N-4-80.3%	0.305	0.35	0.042	0.041	2.859	3.361	17.5529788
		KY/CA							
81A	6/9/92	LAMINATED							
		GC23N/MICROTHENE &							
		C-PLASTIC							
		5/92-1R							
		5/92-2R							
		5/92-3R							
		5/92-4R							
		LAMINATED							
		DOPED OXIDE/SCW							
		AND C-PLASTIC	0.38	23.3	0.098	0.098	1.527	93.604	6031.57895
82A	6/10/92	LAMINATED							
		DOPED OXIDE/SCW							
		AND C-PLASTIC							
		LAMINATED							
		DOPED OXIDE-5/92							
84A	6/26/92	KY 7201 & 711							
		C-PLASTIC							
		CA							
		70%-7201	1.7	26.3	0.031	0.031	21.590	334.011	1447.05882
		75%-7201	0.54	220	0.031	0.033	6.858	2624.672	38171.6049
		85%-711	0.45		0.059		3.003		
		70%-7201 & CA	0.785	1.75	0.032	0.031	9.658	22.225	130.121225
		75%-7201 & CA	0.68	6.4	0.033	0.032	8.113	78.740	870.588235
		85%-711 & CA	0.32		0.062		2.032		
		LAMINATES							
85A	6/30/92	DOPED OXIDE, CA							
		C-PLASTIC, Pb FOIL							
		711 KYANR & Pb DUST							
		70%-W/CA-FOIL	3.7	71.5	0.022	0.025	66.213	1125.984	22243.75
		70%-W/CA-DUST	0.6	12	0.022	0.025	10.737	188.976	11776.2887
		70%-W/O CA-FOIL	2.15	73	0.022	0.026	38.475	1105.391	15570.8408
		70%-W/O CA-DUST	0.32		0.025		5.039		
		75%-W/CA-FOIL	0.097		0.024		1.591		
		75%-W/CA-DUST	0.43		0.024		7.054		
		75%-W/O CA-FOIL	1.25		0.025		19.685		

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
88A	7/13/92	75%-W/O CA-DUST	0.3		0.026		4.543		0.028		984.252		21566.6667
		5/92-DOPED OXIDE KY-711											
		C-PLASTIC											
		.013-C-PLASTIC	0.11		0.013		3.331		0.012		3.773		13.2575758
		.020-DOPED OXIDE	0.65		0.033		7.755						
		.030-DOPED OXIDE	1.15		0.042		10.780		0.042		36.089		234.782609
92A	7/22/92 PG. 167	.040-DOPED OXIDE	1.55		0.05		12.205		0.048		9.268		-24.0591398
		.050-DOPED OXIDE	1.65		0.054		12.030		0.054		12.248		1.81818182
		LEAD DUST & POLYSULFONE	0.043		0.028		0.605						
		PREMIXED W/1.1.1 DRIED PRESSED AT 599F 30 TONS											
		55% BY WT.											
		LAMINATE											
94A	7/28/92	DOPED OXIDE(5/92) KY-711 & KET WITH KY-711	0.305		0.068		1.766		0.068		2.779		57.3770492
		14%-KET/KYN-.050	0.38		0.061		2.453		0.061		2.582		5.26315789
		14%-KET/KYN-.040	0.5		0.051		3.860		0.051		5.713		48
		14%-KET/KYN-.030	0.066		0.025		1.039		0.025		8.976		763.636364
		PPOLYSULFONE											
		LAMINATE											
95A	7/30/92	DOPED OXIDE(5/92) KY-7201 & KET WITH KY-7201	0.305		0.066		1.819		0.066		2.058		13.1147541
		14%-KET/KYN-.050	0.295		0.061		1.904		0.061		2.582		35.5932203
		14%-KET/KYN-.040	0.27		0.052		2.044		0.052		8.707		325.925926
		14%-KET/KYN-.030	0.255		0.043		2.335		0.043		38.454		1547.05882
		14%-KET/KYN-.020	0.243		0.047		2.036		FOR		SHOW		
		14%-KET/KYN-.026					SAMPLE						
96A	8/10/92	LAMINATES											
		DOPED OXIDE W/MICROTHENE KET & MICROTHENE											
		80%-DOPED OXIDE-96A-1	0.62		0.071		3.438		0.071		3.549		3.22580645
		80%-DOPED OXIDE-96A-2	0.46		0.063		2.875		0.063		2.750		-4.34782609

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		THICKNESS (INCH)	RESISTANCE (OHM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER		BEFORE	AFTER	
97A	8/18/92	LAMINATES										
		DOPED OXIDE/KY(8/92)										
		KET/KY(8/92)										
		75%-DOPED OXIDE-97A-1	0.21	1.65	0.052	0.052	1.590	1.65	0.052	12.492	685.714286	
99A	8/21/92	75%-DOPED OXIDE-97A-2	0.23	0.43	0.063	0.063	1.437	0.43	0.063	2.687	86.9565217	
		75%-DOPED OXIDE-97A-3	0.218	0.29	0.067	0.067	1.281	0.29	0.067	1.704	33.0275229	
		LAMINATES										
		DOPED OXIDE/KY										
102A	9/16/92	KET/KY										
		75%-DOPED OXIDE-99A-1	0.25	0.31	0.074	0.074	1.330	0.31	0.074	1.649	24	
		75%-DOPED OXIDE-99A-2	0.22	0.32	0.076	0.076	1.140	0.32	0.076	1.658	45.4545455	
		75%-DOPED OXIDE-99A-3	0.225	0.51	0.06	0.06	1.476	0.51	0.06	3.346	126.666667	
103A	9/23/92	75%-DOPED OXIDE-99A-4	0.185	0.33	0.06	0.06	1.214	0.33	0.06	2.165	78.3783784	
		LAMINATES										
		DOPED OXIDE/MICROTHENE										
		KET/MICROTHENE										
104A	9/29/92	80%-DOPED OXIDE-102A-1	1.55	2.4	0.061	0.061	10.004	2.4	0.062	15.240	52.3413111	
		80%-DOPED OXIDE-102A-2	1.15	1.63	0.073	0.073	6.202	1.63	0.077	8.334	34.3760587	
		80%-DOPED OXIDE-102A-3	1.75	3.4	0.049	0.049	14.061	3.4	0.049	27.318	94.2857143	
		80%-DOPED OXIDE-102A-4	1.13	1.83	0.046	0.046	9.671	1.83	0.048	15.010	55.199115	
105A	10/9/92	LAMINATES										
		WASHED DOPED OXIDE										
		PRECOMPOUNDED										
		C-PLASTIC										
106A	9/29/92	103A-1	0.58	1.5	0.08	0.08	2.854	1.5	0.08	7.382	158.62069	
		103A-2	0.595	6	0.063	0.063	3.718	6	0.063	37.495	908.403361	
		103A-3	0.375	2.8	0.05	0.05	2.953	2.8	0.05	22.047	646.666667	
		103A-4	0.355	12.5	0.04	0.04	3.494	12.5	0.04	123.031	3421.12676	
107A	9/29/92	LAMINATES										
		WASHED DOPED OXIDE										
		PRECOMPOUNDED										
		C-PLASTIC										
108A	9/29/92	104A-1	0.33	8.5	0.047	0.047	2.764	8.5	0.047	71.201	2475.75758	
		104A-2	0.44	3.2	0.058	0.058	2.987	3.2	0.058	21.721	627.272727	
		104A-3	0.31	5.2	0.064	0.064	1.907	5.2	0.064	31.988	1577.41935	
		104A-4	0.355	2.9	0.073	0.073	1.915	2.9	0.073	15.640	716.901408	
109A	9/29/92	104A-5	0.72	10.3	0.048	0.048	5.906	10.3	0.048	84.482	1330.55556	
		104A-6	0.7	5.5	0.062	0.062	4.445	5.5	0.062	34.925	685.714286	
		104A-7	0.455	5.5	0.066	0.066	2.714	5.5	0.066	32.808	1108.79121	
		104A-8	0.54	4.3	0.066	0.066	3.221	4.3	0.066	25.650	696.296296	
110A	10/9/92	KY (7/92) &										
		MICROTHENE (5/92)										

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
109A		80%-LOADING							
		DOPED OXIDE (5/92)							
		10%KY/90%MIC.-105A-1	0.17	0.056	1.195	0.45	0.056	3.164	164.705882
		20%KY/80%MIC.-105A-2	0.185	0.053	1.374	0.78	0.053	5.794	321.621622
		30%KY/70%MIC.-105A-3	0.173	0.053	1.285	1.85	0.053	13.742	969.364162
	40%KY/60%MIC.-105A-4	0.165	0.05	1.299	2.8	0.05	22.047	1596.9697	
110A	10-26-92	KY (7/92) & MICROTHENE (5/92)							
		80%-LOADING							
		DOPED OXIDE (5/92)							
		109A-1	0.29	0.041	2.785	0.87	0.04	8.563	141.666667
		109A-2	0.36	0.04	3.543	4.4	0.042	412.448	12915.873
	109A-3	0.33	0.041	3.169	0.85	0.041	8.162	83.7583149	
	109A-4	0.44	0.039	4.442					
111A	10-29/92	LAMINATES							
		80% DOPED OXIDE(5/92)							
		MICRO.(5/92) & KY(7/92)							
		110A-1	0.225	0.038	2.331	4.9	0.038	50.767	2077.77778
		110A-2	0.35	0.039	3.533	4.8	0.039	48.455	1271.42857
	400F/3 TONS	110A-3	0.22	0.042	2.062	1.75	0.042	16.404	695.454545
	400F/3 TONS	110A-4	0.33	0.041	3.169	0.57	0.041	5.473	72.7272727
112A	10/29/92	LAMINATES							
	5MIN.SOAK/3MIN.CYC.	PRECOMPOUNDED							
		MICRO./DOPED OXIDE							
		85%-LOADING							
		111A-1	1	0.042	9.374	1.95	0.042	18.279	95
	350F/3 TONS	111A-2	2.1	0.043	19.227	3	0.043	27.467	42.8571429
	350F/3 TONS	KY/DOPED OXIDE							
	400F/3 TONS	75%-LOADING							
		111A-3	0.8	0.053	5.943	1.2	0.053	8.914	50
	350F/3 TONS	MICRO./DOPED OXIDE							
		80%-LOADING							
	11/5/92	111A-4	1.8	0.036	19.685	2	0.036	21.872	11.1111111
		LAMINATES							
		75% LOADING							
		DOPED OXIDE(7/92)							
		KY(7/92)							
		14%KET(9/92)							
		KY(7/92)							
		112A-1	0.15	0.089	0.664		0.089	0.000	-100
		112A-2	0.165	0.088	0.738		0.088	0.000	-100

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
113A	325F/3 TONS 11/10/92	LAMINATES 80% LOADING											
		DOPED OXIDE(7/92)											
		MICROTHENE(5/92)											
		PRECOMPOUNDED C-PLASTIC											
	325F/3 TONS 11/10/92	112A-3	0.46	0.069	0.069	0.069	2.625	0.000	0.069	0.069	0.000	0.000	-100
		112A-4	0.58	0.075	0.075	0.075	3.045	0.000	0.075	0.075	0.000	0.000	-100
		LAMINATES											
		80% DOPED OXIDE(7/92)											
	325F/3 TONS 11/10/92	MICROTHENE(5/92) CA											
		PRECOMPOUNDED C-PLASTIC											
114A	325F/3 TONS 11/10/92	113A-1	0.49	0.064	0.064	0.064	3.014	28.912	0.064	0.064	28.912	28.912	859.183673
		113A-2	0.37	0.066	0.066	0.066	2.207	27.440	0.066	0.066	27.440	27.440	1143.24324
		113A-3	0.36	0.074	0.074	0.074	1.915	4.522	0.074	0.074	4.522	4.522	136.111111
		113A-4	0.41	0.068	0.068	0.068	2.374	4.111	0.068	0.068	4.111	4.111	73.1707317
	325F/3 TONS 11/24/92	LAMINATES											
		80% DOPED OXIDE(7/92)											
		MICROTHENE(5/92) CA											
		PRECOMPOUNDED C-PLASTIC											
	325F/3 TONS 11/24/92	114A-1	0.43	0.062	0.062	0.062	2.731	11.113	0.062	0.062	11.113	11.113	306.976744
		114A-2	0.42	0.069	0.069	0.069	2.396	7.760	0.069	0.069	7.760	7.760	223.809524
		114A-3	0.46	0.068	0.068	0.068	2.663	5.616	0.068	0.068	5.616	5.616	110.869565
		114A-4	0.64	0.076	0.076	0.076	3.315	5.439	0.076	0.076	5.439	5.439	64.0625
115A	325F/3 TONS 11/24/92	LAMINATES											
		80% LOADING DOPED OXIDE											
		20% MICROTHENE											
		WASHING TECH. PRECOMPOUNDED C-PLASTIC .2%/07GMS CA											
	325F/3 TONS	325F/3 TONS	0.38	0.073	0.073	0.073	2.049	2.843	0.073	0.073	2.843	2.843	38.7426901

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
116A	325F/3 TONS	115A-2 COARSE-X	0.35		0.072		1.914		0.072		2.843		48.5714286
	325F/3 TONS	115A-3 MEDIUM-X	0.46		0.062		2.921		0.062		6.096		108.695652
	325F/3 TONS	115A-4 MEDIUM-X	0.58		0.067		3.408		0.067		6.934		103.448276
	11/25/92	LAMINATES											
		80% LOADING DOPED OXIDE											
		20% MICROTHENE											
		PRECOMPOUNDED C-PLASTIC											
		2%/.07GMS CA											
		325F/3 TONS											
		116A-1 COARSE	0.37		0.077		1.892						
117A	325F/3 TONS	116A-2 COARSE	0.3		0.071		1.664						
	325F/3 TONS	116A-3 MEDIUM	0.88		0.067		5.171						
	325F/3 TONS	116A-4 MEDIUM	0.61		0.066		3.639						
	12/03/92	LAMINATES											
		80% LOADING DOPED OXIDE											
		20% MICROTHENE											
		PRECOMPOUNDED C-PLASTIC											
		.15% TO .45% CA											
		325F/3 TONS											
		117-1A (.15%)	0.38		0.071		2.107		0.071		5.434		157.894737
118A		117-2A (.20%)	0.51		0.071		2.828		0.071		6.377		125.490196
		117-3A (.25%)	0.42		0.068		2.432		0.066		4.176		71.7171717
		117-4A (.30%)	0.56		0.068		3.242		0.068		5.674		75
		117-5A (.35%)	0.42		0.071		2.329						
		117-6A (.40%)	0.46		0.065		2.786						
		117-7A (.45%)	0.64		0.064		3.937						
	12/07/92	LAMINATES											
		80% LOADING DOPED OXIDE											
		20% MICROTHENE											
	118	PRECOMPOUNDED C-PLASTIC											
118A		.15% TO .45% CA											
		325F/3 TONS											
		118-1A (.15%)	0.4		0.068		2.316						

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER		
119A	12/04/92 119A	118-2A (.20%)	0.4		0.071		2.218							
		118-3A (.25%)	0.38		0.068		2.200		0.4		0.069		2.282	19.4554238
		118-4A (.30%)	0.33		0.068		1.911		0.4		0.067		2.350	35.3233831
		118-5A (.35%)	0.3		0.068		1.737		0.46		0.069		2.625	15
		118-6A (.40%)	0.4		0.069		2.282		0.45		0.068		2.605	25
		118-7A (.45%)	0.36		0.068		2.084							
THIN LAMINATES														
120A	12/16/92	80% LOADING DOPED OXIDE												
		20% MICROTHENE PRECOMPOUNDED C-PLASTIC												
		.25% CA												
		325F/3 TONS												
		119-1A	0.5		0.038		5.180							
		119-2A	0.34		0.038		3.523							
		119-3A	0.225		0.033		2.684							
		119-4A	0.42		0.03		5.512							
		HAND COMPOUNDED CARBON PLASTIC												
		120-1A 350F	0.43		0.058		2.919							
		120-2A 350F	0.51		0.061		3.292		0.52		0.059		3.470	36.8421053
		120-3A 375F	0.38		0.059		2.536		0.56		0.062		3.556	27.2727273
121A	12/17/92	120-4A 375F	0.44		0.062		2.794							
		PRECOMPOUNDED CARBON PLASTIC												
		120-5A	1.3		0.056		9.139		1.95		0.056		13.709	50
		120-6A	2.05		0.058		13.915		2.95		0.058		20.024	43.902439
		LAMINATES												
		80% LOADING DOPED OXIDE MICROTHENE (5/92)												
122A	12/17/92	.25% CA												
		HANDCOMPOUNDED CARBON PLASTIC												
		121-1A	0.43		0.075		2.257							
		121-2A	0.43		0.07		2.418							
		LAMINATES												
		2.60G KETBLACK 10.37G MICRO (5/92) 325F/15 TONS 0.060" SHIM												

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
123A	123A 01/04/93	LAMINATES 80% LOADING DOPED OXIDE 20% MICROTHENE HANDCOMPOUNDED C-PLASTIC 30% TO 100% CA	122-1A	0.46	0.051	0.051	3.551	1.4	0.051	10.807	0.051	10.807	204.347826		204.347826
			122-2A	0.43	0.05	0.05	3.386	5.4	0.051	41.686	0.051	41.686	1131.19015		1131.19015
			122-3A	0.41	0.05	0.05	3.228	1.45	0.051	11.193	0.051	11.193	246.724055		246.724055
			122-4A	0.43	0.052	0.052	3.256	0.82	0.052	6.208	0.052	6.208	90.6976744		90.6976744
			123-1A (.30%)	0.49	0.08	0.08	2.411	0.58	0.08	2.854	0.08	2.854	18.3673469		18.3673469
			123-2A (.35%)	0.36	0.081	0.081	1.750	0.37	0.081	1.798	0.081	1.798	2.77777778		2.77777778
			123-3A (.40%)	0.58	0.08	0.08	2.854	0.74	0.081	3.597	0.081	3.597	26.0110685		26.0110685
			123-4A (.45%)	0.43	0.081	0.081	2.090	0.51	0.08	2.510	0.08	2.510	20.0872093		20.0872093
			123-5A (.50%)	0.44	0.078	0.078	2.221								
			123-6A (.55%)	0.65	0.078	0.078	3.281								
			123-7A (.60%)	0.62	0.076	0.076	3.212								
			123-8A (.65%)	0.6	0.076	0.076	3.108								
			123-9A (.70%)	0.66	0.078	0.078	3.331								
			123-10A (.75%)	0.6	0.076	0.076	3.108								
			123-11A (.80%)	0.9	0.08	0.08	4.429								
124	124A 07-JAN-93	LAMINATES 80% LOADING DOPED OXIDE 20% MICROTHENE HANDCOMPOUNDED C-PLASTIC 1.5% TO 3.0% CA	123-12A (.85%)	0.68	0.08	0.08	3.346								
			123-13A (.90%)	0.6	0.072	0.072	3.281								
			123-14A (.95%)	0.52	0.075	0.075	2.730								
			123-15A (1.00%)	0.54	0.075	0.075	2.835								
			124-1A (1.5%)	0.62	0.075	0.075	3.255								
			124-2A (2.0%)	0.98	0.077	0.077	5.011								
			124-3A (2.5%)	0.83	0.076	0.076	4.300								
			124-4A (3.0%)												
			124-5A (3.5%)												
			124-6A (4.0%)												
			124-7A (4.5%)												
			124-8A (5.0%)												
			124-9A (5.5%)												
			124-10A (6.0%)												
			124-11A (6.5%)												

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
125A	125A 01/12/93	124-4A (3.0%)	0.66		0.077		3.375		
		LAMINATES							
		TEMP 230F TO 400F							
		85% DOPED OXIDE PELLETS							
		HANDCOMPOUNDED							
		C-PLASTIC							
		125-1A (300F)	0.41		0.057		2.832		
		125-2A (300F)	0.73		0.057		5.042		
		125-3A (350F)	0.42		0.05		3.307		
		125-4A (350F)	0.59		0.051		4.555		
		125-5A (375F)	0.45		0.051		3.474		
		125-6A (375F)	0.44		0.052		3.331		
		125-7A (400F)	0.39		0.051		3.011		
		125-8A (400F)	0.39		0.051		3.011		
		125-11A (275F)	0.58		0.057		4.006		
		125-12A (275F)	0.38		0.057		2.625		
126A	126A 01/14/93	LAMINATES							
		80% TO 90% LOADING							
		DOPED OXIDE(7/92)							
		.35% CA							
		SAMPLES 1&2							
		.30% CA							
		SAMPLES 3-7							
		HANDCOMPOUNDED							
		C-PLASTIC							
		MICROTHENE (5/92)							
		325F/3 TONS							
		126-1A (80%)	1.45		0.061		9.358		
		126-2A (80%)	2.85		0.061		18.394		25
		126-3A (85%)	0.32		0.08		1.575	0.4	
		126-4A (85%)	0.27		0.076		1.399	0.33	
		275F/3 TONS							22.2222222
129A	01/15/93	126-6A (82.5%)	1.4		0.073		7.550	1.45	3.57142857
		126-7A (82.5%)	0.52		0.062		3.302	0.53	1.92307692
		LAMINATES							
		85% DOPED OXIDE PELLETS							
		14% TO 22%							
		KET (9/92)							
		325F/3 TONS							
		129-1A (15%)	0.54		0.05		4.252		
		129-2A (15%)	0.64		0.048		5.249		
		129-3A (16%)	0.55		0.049		4.419		
		129-4A (16%)	0.56		0.049		4.499		

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
130A	130A 01/19/93	129-5A (16%)	0.75		0.05		5.906								
		129-6A (18%)	0.66		0.049		5.303								
		129-7A (22%)	0.63		0.051		4.863								
		129-8A (22%)	0.38		0.05		2.992								
		LAMINATE 325F/3 TONS													
131A	131A 01/27/93	130-1A (18%)	0.46		0.049		3.696		0.71		0.049		5.705		54.3478261
		130-2A (18%)	0.46		0.044		4.116		0.76		0.045		6.649		61.5458937
		130-3A (16%)	0.43		0.044		3.848		0.53		0.044		4.742		23.255814
		130-4A (16%)	0.49		0.043		4.486		0.64		0.044		5.727		27.6437848
131A	131A 01/27/93	LAMINATE 325F/3 TONS													
		131-1A(3 TONS)	0.58		0.061		3.743								
		131-3A(15 TONS)	0.74		0.055		5.297								
		131-4A(15 TONS)	0.51		0.052		3.861								
		131-5A(3 TONS)	0.78		0.076		4.041								
132A	132A 01/28/93	LAMINATE 325F/3 TONS													
		132-1A(3 TONS)	1.3		0.057		8.979								
		132-2A(3 TONS)	1.5		0.048		12.303								
		132-3A(15 TONS)	0.96		0.05		7.559								
		132-4A(15 TONS)	0.79		0.051		6.099								
133A	133A 01/28/93	LAMINATE 325F/3 TONS													
		133-1A(3 TONS)	0.36		0.069		2.054								
		133-2A(3 TONS)	0.32		0.065		1.938								
		133-3A(15 TONS)	0.44		0.051		3.397								
		133-4A(15 TONS)	0.5		0.052		3.786								
134A	134A 01/28/93	LAMINATE 325F/3 TONS													
		134-1A(3 TONS)	0.76		0.058		5.159		0.83		0.058		5.634		9.21052632
		134-2A(3 TONS)	0.63		0.057		4.351		0.69		0.058		4.684		7.63546798
		134-3A(15 TONS)	0.85		0.049		6.830		0.72		0.049		5.785		-15.2941176
		134-4A(15 TONS)	0.76		0.051		5.867		0.68		0.05		5.354		-8.73684211
135A	135A 01/28/93	LAMINATE 325F/3 TONS													
		135-1A(.010")	0.65		0.029		8.824		0.61		0.03		8.005		-9.28205128
		135-2A(.010")	0.6		0.034		6.948		0.57		0.034		6.600		-5
		135-3A(.006")	0.56		0.029		7.602		0.51		0.029		6.924		-8.92857143
		135-4A(.006")	0.62		0.029		8.417		0.72		0.029		9.775		16.1290323
136A	02/01/93	LAMINATE 325F/3 TONS													
		136-1A(22%)	0.39		0.034		4.516								

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
137A	02/03/93	LAMINATE 325F/3 TONS 137-1A 137-2A 137-3A 137-4A	0.57		0.033		6.800								
			0.34		0.035		3.825								
			0.39		0.034		4.516								
MRP	02/03/93	LAMINATE 325F/3 TONS MRP-1 MRP-2 MRP-3 MRP-4	0.48		0.056		3.375		0.59		0.056		4.148		22.9166667
			0.41		0.061		2.646		0.48		0.06		3.150		19.0243902
			0.49		0.054		3.572		0.89		0.054		6.489		81.6326531
			0.43		0.058		2.919		0.47		0.058		3.190		9.30232558
138A	02/04/93	LAMINATE 325F/3 TONS 138-1A 138-2A 138-3A 138-4A	0.34		0.03		4.462								
			0.6		0.032		7.382								
			0.43		0.036		4.703								
			0.35		0.035		3.937								
139A	02/05/93	LAMINATE 325F/3 TONS 139-1A(18%) 139-2A(18%) 139-3A(22%) 139-4A(22%)	0.39		0.022		6.979								
			0.36		0.025		5.669								
			0.33		0.026		4.997								
			0.4		0.027		4.997								
BR AND R3	02/05/93	LAMINATE 325F/3 TONS BR-1 BR-2 R3-1 R3-2	0.76		0.039		7.672								
			0.85		0.039		8.581								
			0.47		0.042		4.406								
			0.51		0.049		4.098								
EXTRUDED 3/24/93		168-1A 100/115/120/125 168-2A 100/110/120/125 168-3A LAMINATION STOPPED.	1.2												
169A	03/25/93	LAMINATE 325F/3 TONS 169-1A	0.89		0.041		8.5461878		>100						

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
		169-2A	0.52	0.041	4.9932783	>100									
LAMINATE 325F/3 TONS															
170A	03/26/93														
		170-1A	0.68	0.041	6.5296716	0.66					0.041		6.337622431	-2.94117647	
		170-2A	0.9	0.041	8.6422124	0.86					0.041		8.258114077	-4.44444444	
LAMINATE 325F/3 TONS															
171A	03/30/93														
		171-1A	0.35	0.035	3.9370079	0.74					0.035		8.323959505	111.428571	
		171-2A	0.68	0.035	7.6490439	1.05					0.036		11.48293963	50.122549	
		171-3A	0.52	0.039	5.2493438										
		171-4A	0.55	0.038	5.6983009										
LAMINATE 325F/3 TONS															
173A	04/2/93														
		173-1A	0.34	0.039	3.4322633	0.36					0.04		3.543307087	3.23529412	
		173-2A	0.41	0.039	4.1389057	0.48					0.041		4.60917995	11.3622844	
LAMINATE 325F/3 TONS															
175A	04/05/93														
		175-1A(160)	0.55	0.041	5.281352	0.79					0.041		7.585942001	43.6363636	
		175-2A(160)	0.39	0.042	3.655793	0.53					0.042		4.968128984	35.8974359	
		175-3A(180)	0.47	0.043	4.3032412	0.68					0.043		6.22596594	44.6808511	
		175-4A(180)	0.44	0.042	4.1244844	0.58					0.043		5.310382714	28.7526427	
LAMINATE 325F/3 TONS															
176A	04/06/93														
		176-1A(160)	0.42	0.04	4.1338583	0.43					0.04		4.232283465	2.38095238	
		176-2A(160)	0.49	0.04	4.8228346	0.49					0.041		4.705204532	-2.43902439	
		176-3A(180)	0.38	0.039	3.836059	0.39					0.039		3.937007874	2.63157895	
		176-4A(180)	0.35	0.038	3.6261915	0.36					0.04		3.543307087	-2.28571429	
		176-1A	0.42	0.04	4.1338583	0.67					0.04		6.594488189	59.5238095	
		176-3A	0.38	0.039	3.836059	0.59					0.04		5.807086614	51.3815789	
		176-4A	0.35	0.038	3.6261915	0.5					0.04		4.921259843	35.7142857	

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER		
177A	04/12/93	*176-3A *SAMPLE TESTED FOR 30 DAYS 176-3A READING TAKEN AFTER 1 DAY 176-3A READING TAKEN AFTER 2 DAYS	0.38		0.039		4.134		0.9		0.04		8.858267717	114.278368
			0.38		0.039		4.134		0.64		0.039		6.46073087	56.282798
			0.38		0.039		4.134		0.833		0.04		8.198818898	98.3265336
		LAMINATE 325F/3 TONS												
			0.61		0.041		5.8574995		0.53		0.041		5.089302862	-13.1147541
			0.81		0.044		7.2476736		0.74		0.042		6.936632921	-4.29159318
			1.05		0.043		9.6136239		0.77		0.042		7.217847769	-24.9206349
			0.84		0.044		7.5161059		0.65		0.043		5.951290972	-20.8194906
178A	04/14/93	LAMINATE 325F/3 TONS												
			0.54		0.046		4.6217049		0.58		0.046		4.964053406	7.40740741
			0.64		0.047		5.361032		0.68		0.045		5.949256343	10.9722222
			0.53		0.045		4.6369204		0.48		0.045		4.199475066	-9.43396226
			0.45		0.041		4.3211062		0.48		0.041		4.60917995	6.66666667
179A	04/15/93	LAMINATE 325F/3 TONS												
			0.39		0.045		3.4120735		0.46		0.045		4.024496938	17.9487179
			0.31		0.043		2.838308		0.39		0.043		3.570774583	25.8064516
			0.28		0.043		2.563633		0.34		0.043		3.11298297	21.4285714
			0.31		0.043		2.838308		0.38		0.043		3.479216261	22.5806452
181A	04/28/93	LAMINATE 325F/3 TONS												
			0.47		0.063		2.9371329		0.58		0.062		3.683007366	25.3946465
			0.4		0.059		2.6691579		0.56		0.057		3.86793756	44.9122807
			0.54		0.064		3.3218504		0.61		0.064		3.75246063	12.962963

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
181-4A(180)			0.55	0.064	3.3833661	0.58	0.064	3.567913386	5.45454545
182A 4V BATTERIES FOR PASTE ADHESION	04/28/93	LAMINATE 325F/3 TONS							
		182-1A(200) SANDED	0.68	0.073	3.6673498				
		182-2A(200)	0.7	0.06	4.5931759				
		Pb THEN SANDED							
		182-3A(180) SANDED	0.68	0.071	3.7706554				
		182-4A(180)	0.6	0.058	4.0727668				
		Pb THEN SANDED							
		IR at corner.							
183A	04/29/93	LAMINATE 325F/3 TONS							
		183-1A	0.38	0.043	3.4792163	0.54	0.044	4.831782391	38.8755981
		183-2A	0.38	0.043	3.4792163	0.55	0.048	4.511154856	29.6600877
		183-3A	0.38	0.059	2.5357	0.55	0.059	3.670092086	44.7368421
		183-4A	0.38	0.057	2.6246719	0.58	0.059	3.870278927	47.4576271
184A	05/04/93	LAMINATE 325F/3 TONS							
		184-1A	0.58	0.046	4.9640534	0.78	0.046	6.67579596	34.4827586
		184-2A	0.5	0.046	4.2793564	0.8	0.047	6.701289998	56.5957447
		184-3A	0.58	0.05	4.5669291	0.76	0.051	5.866913695	28.4651792
185A	05/05/93	LAMINATE 325F/3 TONS							
		185-1A	0.38	0.055	2.7201145	0.58	0.055	4.151753758	52.6315789
		185-2A	0.29	0.048	2.3786089	0.41	0.05	3.228346457	35.7241379
		THICK SUBSTRATE							
186A	05/05/93	LAMINATE 325F/3 TONS							
		186-1A	1	0.041	9.6024582	1.55	0.042	14.52943382	51.3095238
		186-2A	0.82	0.041	7.8740157	1.3	0.043	11.90258194	51.1627907
187A		LAMINATE 330F/2 TONS							
		187-1A	0.155	0.03	2.0341207	10.5	0.03	137.7952756	6674.19355

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
188A		LAMINATE 330F/2 TONS 187-2A 187-3A 187-4A	0.135		0.029		1.832745		20		0.029		271.5177844		14714.8148
			0.135		0.029		1.832745		6.2		0.029		84.17051317		4492.59259
			0.155		0.03		2.0341207		8.1		0.03		106.2992126		5125.80645
189A	06/14/93	LAMINATE 295F/3 TONS 188-1A 188-2A 188-3A 188-4A	0.14		0.028		1.9685039		6		0.03		78.74015748		3900
			0.14		0.031		1.7780036		9		0.03		118.1102362		6542.85714
			0.135		0.031		1.7145034		8.1		0.031		102.8702057		5900
			0.155		0.031		1.9685039		9.6		0.031		121.9202438		6093.54839
189A	06/14/93	LAMINATE 295F/3 TONS 189-1A	0.97		0.045		8.486								
190A	06/16/93	LAMINATE 295F/3 TONS 190-1A 190-2A 190-3A 190-4A	0.47		0.051		3.6282229		0.7		0.051		5.403736298		48.9361702
			0.54		0.045		4.7244094		0.83		0.045		7.261592301		53.7037037
			0.74		0.086		3.3876579								
			0.78		0.092		3.337898								
191A	06/18/93	LAMINATE 295F/3 TONS 191-1A(006)SANDED 191-2A(006) 191-2A	0.25		0.044		2.2369363		1.6		0.044		14.31639227		540
			0.255		0.045		2.2309711		0.97		0.044		8.679312813		289.037433
			0.255		0.045		2.2309711		0.38		0.044		3.400143164		52.4064171
192A	06/18/93	LAMINATE 295F/3 TONS 191-3A(007)SANDED 191-4A(007) 192-1A 192-2A	0.23		0.043		2.1058414		0.48		0.044		4.294917681		103.952569
			0.29		0.044		2.5948461		0.58		0.044		5.189692198		100
			1.3		0.051		10.03551		3.5		0.049		28.12148481		180.21978
			1.9		0.049		15.265949		4.4		0.05		34.64566929		126.947368
193A	06/18/93	LAMINATE 295F/3 TONS 193-1A(SANDED) 193-2A	0.19		0.062		1.2065024		0.82		0.062		5.207010414		331.578947
			0.26		0.058		1.7648656		2.2		0.059		14.68036834		731.812256

READING TAKEN AFTER BEING STORED FOR 2.5 MONTHS

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
194A	06/24/93	LAMINATE 295F/3 TONS 194-1A(.008") 194-2A(.008") 194-3A(.010") 194-4A(.010")	0.265		0.031		3.3655067		8.5		0.032		104.5767717		3007.31132
			0.32		0.042		2.999625		>100		0.043				
			0.29		0.04		2.8543307		>100		0.04				
			0.31		0.034		3.5896248		44		0.034		509.4951366		14093.5484
195A	06/28/93	LAMINATE 295F/3 TONS 195-1A 195-2A	0.46		0.046		3.9370079		0.65		0.046		5.5631633		41.3043478
			0.58		0.046		4.9640534		0.72		0.046		6.162273194		24.137931
196A	06/28/93	LAMINATE 295F/3 TONS 196-1A 196-2A	1.15		0.044		10.289907		1.15		0.045		10.06124234		-2.22222222
			1.05		0.045		9.1863517		1.3		0.045		11.3735783		23.8095238
197A	06/29/93	LAMINATE 295F/3 TONS 197-1A(315F) 197-2A(315F) 197-3A(335F) 197-4A(335F) 197-5A(355F) 197-6A(355F) 197-7A(375F) 197-8A(375F) 197-9A(400F) 197-10A(400F)	0.24		0.044		2.1474588		0.7		0.045		6.124234471		185.185185
			0.275		0.045		2.4059493		0.65		0.045		5.686789151		136.363636
			0.225		0.045		1.9685039		0.73		0.045		6.386701662		224.444444
			0.36		0.051		2.7790644		0.81		0.051		6.252894859		125
			0.24		0.044		2.1474588		0.37		0.045		3.237095363		50.7407407
			0.22		0.045		1.9247594		0.275		0.045		2.405949256		25
			0.235		0.045		2.055993		0.29		0.045		2.537182852		23.4042553
			0.215		0.045		1.8810149		0.3		0.045		2.624671916		39.5348837
			0.205		0.045		1.7935258		0.275		0.045		2.405949256		34.1463415
			0.2		0.046		1.7117426		0.275		0.045		2.405949256		40.5555556
198A	06/29/93	LAMINATE 295F/3 TONS 198-1A(315F) 198-2A(315F) 198-3A(335F) 198-4A(335F) 198-5A(355F) 198-6A(355F) 198-7A(375F) 198-8A(375F) 198-9A(400F)	0.43		0.049		3.4549253		0.86		0.049		6.909850554		100
			0.41		0.05		3.2283465		1.25		0.05		9.842519685		204.878049
			0.295		0.047		2.4711007		0.82		0.047		6.868822248		177.966102
			0.32		0.052		2.4227741		0.54		0.052		4.08431254		68.75
			0.28		0.046		2.3964396		1.75		0.044		15.65855404		553.409091
			0.23		0.046		1.9685039		4		0.044		35.79098067		1718.18182
			0.21		0.047		1.7590886		1.95		0.046		16.5894899		848.757764
			0.36		0.049		2.8924956		0.65		0.048		5.331364829		84.3171296
			0.245		0.048		2.0095144		1.2		0.046		10.27045532		411.091393

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM) AFTER	THICKNESS (INCH)		RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER					
199A	07/21/93	198-10A(400F)	STABILITY TESTING WAS SHORTENED BY ONE DAY ON SAMPLES 1-4										
			PROBLEM WITH POWER SUPPLY ON SAMPLES 5A-8A										
			LAMINATE 295F/3 TONS										
			199-1A(NOT SANDED)										
200A	07/23/93	199-2A(NOT SANDED)	0.66		0.044		5.9055118						
			0.62		0.043		5.676616						
			LAMINATE 295F/3 TONS										
			199-3A(SANDED)										
201A	07/23/93	199-4A(SANDED)	0.31		0.044		2.773801	0.5		0.045		4.374453193	57.7060932
			0.37		0.043		3.3876579	0.54		0.044		4.831782391	42.6289926
			LAMINATE 295F/3 TONS										
			200-1(SANDED)										
202A	07/23/93	200-2(SANDED)	0.45		0.043		4.1201245	0.58		0.044		5.189692198	25.959596
			0.47		0.045		4.111986	0.66		0.044		5.905511811	43.6170213
			LAMINATE 295F/3 TONS										
			201-1(325)										
203A	07/23/93	201-2(350)	0.32		0.046		2.7387881	0.4		0.043		3.662332906	33.7209302
			0.295		0.043		2.7009705	0.4		0.043		3.662332906	35.5932203
			LAMINATE 295F/3 TONS										
			201-3(375)										
204A	07/23/93	201-4(400)	0.34		0.044		3.0422334	0.45		0.045		3.937007874	29.4117647
			0.31		0.044		2.773801	0.58		0.044		5.189692198	87.0967742
			LAMINATE 295F/3 TONS										
			201-5(425)										
205A	07/23/93	202-1(325)	0.31		0.044		2.773801	1.4		0.044		12.52684324	351.612903
			LAMINATE 295F/3 TONS										
			202-2(350)										
			202-3(375)										
206A	07/23/93	202-4(400)	0.41		0.043		3.7538912	0.71		0.043		6.500640908	73.1707317
			0.31		0.043		2.838308	0.48		0.043		4.394799487	54.8387097
			LAMINATE 295F/3 TONS										
			202-5(425)										
207A	07/23/93	203-1(325)	0.35		0.044		3.1317108	0.54		0.044		4.831782391	54.2857143
			0.38		0.043		3.4792163	0.54		0.044		4.831782391	38.8755981
			LAMINATE 295F/3 TONS										
			203-3(375)										
208A	07/23/93	203-4(400)	0.295		0.044		2.6395848	0.98		0.044		8.768790265	232.20339
			LAMINATE 295F/3 TONS										
			203-1(325)										
			203-2(350)										
209A	07/23/93	203-3(375)	0.34		0.044		3.0422334	3.1		0.042		29.05886764	855.182073
			0.42		0.044		3.758053	2.2		0.044		19.68503937	423.809524
			LAMINATE 295F/3 TONS										
			203-4(400)										
210A	07/27/93	204-1A(250)	0.36		0.044		3.2211883	5		0.042		46.86914136	1355.02646
			0.5		0.044		4.4738726	3		0.043		27.4674968	513.953488
			LAMINATE 300F/3 TONS										
			204-2A(275)										
211A	07/27/93	204-3A(300)	0.62		0.046		5.3064019	1.6		0.046		13.69394043	158.064516
			0.45		0.044		4.0264853	0.83		0.044		7.42662849	84.4444444
			LAMINATE 300F/3 TONS										
			204-4A(325)										
212A	07/27/93	204-5A(350)	0.51		0.045		4.4619423	0.68		0.045		5.949256343	33.3333333
			0.51		0.045		4.4619423	0.98		0.045		8.573928259	92.1568627
			LAMINATE 300F/3 TONS										
			204-6A(375)										
213A	07/27/93	204-1A(250)	0.47		0.044		4.2054402	2.9		0.044		25.94846099	517.021277
			0.46		0.044		4.1159628	2.35		0.045		20.55993001	399.516908
			LAMINATE 300F/3 TONS										
			204-2A(275)										

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
205A SEE BATTERY BUILD															
206A	8/10/93	LAMINATE 300F/3 TONS 206-1A(SP006) 206-2A(SP006)	0.275 0.25		0.053 0.052		2.0427871 1.8927922		0.34 0.31		0.053 0.053		2.525627693 2.30277819		23.6363636 21.6603774
		206-3A(SP007) 206-4A(SP007)	0.36 0.23		0.052 0.053		2.7256208 1.7085129		0.48 0.34		0.052 0.052		3.634161114 2.574197456		33.3333333 50.6688963
207A	8/10/93	LAMINATE 300F/3 TONS 207-1A(SP006) 207-2A(SP006)	0.83 0.48		0.043 0.041		7.5993408 4.60918		1.65 0.64		0.042 0.042		15.46681665 5.99250094		103.528399 30.1587302
		207-3A(SP007) 207-4A(SP007)	0.96 0.89		0.043 0.042		8.789599 8.3427072		1 0.86		0.044 0.041		8.947745168 8.258114077		1.79924242 -1.01397643
208A	8/11/93	LAMINATE 300F/3 TONS 208-1A 208-2A 208-3A 208-4A	0.4 0.5 0.3 0.32		0.037 0.038 0.036 0.038		4.2562247 5.1802735 3.2808399 3.3153751		0.6 0.7 0.54 0.73		0.039 0.038 0.037 0.039		6.056935191 7.252382926 5.745903384 7.369271149		42.3076923 40 75.1351351 122.275641
209A	8/16/93	LAMINATE 300F/3 TONS 209-1A(SANDED) 209-2A	0.96 1.35		0.051 0.053		7.4108384 10.028228		3.4 4.3		0.051 0.053		26.24671916 31.941762		254.166667 218.518519
210A RIBBON FROM DE WAL	8/24/93	LAMINATE 300F/3 TONS 210-1A 210-2A 210-3A 210-4A	0.28 0.23 0.41 0.56		0.033 0.033 0.041 0.042		3.3404915 2.7439752 3.9370079 5.2493438		13.75 11 2.4 24		0.033 0.034 0.043 0.043		164.0419948 127.3737842 21.97399744 219.7399744		4810.71429 4541.94373 458.139535 4086.04651
211A	9/2/93	LAMINATE 300F/3 TONS													

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
212A	9/8/93	LAMINATE 300F/3 TONS	0.56	0.032	6.8897638	0.69	0.03	9.05511811	31.4285714
			0.41	0.031	5.2070104	0.62	0.031	7.874015748	51.2195122
			0.32	0.024	5.2493438	0.56	0.024	9.186351706	75
			0.33	0.023	5.6487504	0.8	0.024	13.12335958	132.323232
213A	9/16/93	LAMINATE 350F/3 TONS	0.86	0.044	7.6950608	1.25	0.044	11.18468146	45.3488372
			0.99	0.044	8.8582677	4.4	0.044	39.37007874	344.444444
			0.64	0.043	5.8597326	2.3	0.043	21.05841421	259.375
			0.72	0.043	6.5921992	1.9	0.043	17.3960813	163.888889
214A	9/20/93	LAMINATE 350F/3 TONS	2.6	0.035	29.246344				
			3.4	0.036	37.182852				
			3.8	0.035	42.744657				
			2.8	0.036	30.621172				
215A	9/22/93	LAMINATE 350F/3 TONS	2.5	0.04	24.606299				
			3	0.036	32.808399				
			0.5	0.067	2.9380656				
			0.6	0.082	2.8807375				
216A	9/27/93	LAMINATE 350F/30 TONS	0.84	0.081	4.082823				
			0.82	0.081	3.9856129				
			0.86	0.081	4.1800331				
			*SAMPLES NOT SURFACE TREATED						
215A	9/22/93	LAMINATE 350F/3 TONS	0.45	0.022	8.0529707	8.3	0.022	148.5325698	1744.44444
			0.3	0.021	5.624297	6.9	0.022	123.4788833	2095.45455
			0.34	0.022	6.0844667	9.5	0.022	170.0071582	2694.11765
			0.36	0.022	6.4423765	16	0.022	286.3278454	4344.44444
216A	9/27/93	LAMINATE 350F/30 TONS	0.37	0.024	6.0695538	3.7	0.024	60.69553806	900
			0.285	0.022	5.1002147	1.7	0.021	31.87101612	524.895572
			0.34	0.021	6.3742032	0.92	0.021	17.24784402	170.588235
			0.37	0.02	7.2834646	1.9	0.02	37.4015748	413.513514

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
217A	9/29/93	LAMINATE 300F/3 TONS							
		217-1A	0.48	0.052	3.6341611	0.66	0.052	4.996971532	37.5
		217-2A	0.43	0.05	3.3858268	0.5	0.05	3.937007874	16.2790698
		217-3A	0.47	0.052	3.5584494	0.51	0.052	3.861296184	8.5106383
		217-4A	0.46	0.05	3.6220472	0.6	0.05	4.724409449	30.4347826
218A	9/29/93	LAMINATE 300F/3 TONS							
		218-1A	0.9	0.051	6.947661				
		218-2A	1	0.051	7.7196233				
		218-3A	0.7	0.051	5.4037363				
		218-4A	0.73	0.051	5.635325				
219A	10/4/93	LAMINATE 350F/3 TONS							
		219-1A(30 TONS)	0.46	0.038	4.7658516	0.73	0.038	7.563199337	58.6956522
		219-2A(30 TONS)	0.4	0.038	4.1442188	0.74	0.038	7.666804807	85
		219-3A(3 TONS)	0.37	0.039	3.73511	0.8	0.04	7.874015748	110.810811
		219-4A(3 TONS)	0.43	0.04	4.2322835	0.77	0.04	7.578740157	79.0697674
220A	10/6/93	LAMINATE 300F/3 TONS							
		220-1A	0.34	0.021	6.3742032	0.88	0.022	15.7480315	147.058824
		220-2A	0.3	0.019	6.2163282	0.69	0.019	14.29755491	130
		220-3A	0.28	0.02	5.511811	0.54	0.02	10.62992126	92.8571429
		220-4A	0.34	0.019	7.045172	0.7	0.019	14.50476585	105.882353
221A	10/11/93	LAMINATE 300F/3 TONS							
		221-1A	0.83	0.045	7.2615923	1.15	0.045	10.06124234	38.5542169
		221-2A	0.81	0.044	7.2476736	1.1	0.044	9.842519685	35.8024691
		221-3A	0.85	0.045	7.4365704	1	0.045	8.748906387	17.6470588
		221-4A	0.92	0.044	8.2319256	1.3	0.044	11.63206872	41.3043478
222A	10/15/93	LAMINATE 300F/3 TONS							
		222-1A	0.8	0.026	12.11387	1.15	0.026	17.41368867	43.75
		222-2A	1.2	0.025	18.897638	1.1	0.025	17.32283465	-8.33333333
		222-3A	0.78	0.025	12.283465	1.15	0.025	18.11023622	47.4358974
		222-4A	0.91	0.025	14.330709	0.82	0.025	12.91338583	-9.89010989
223A	10/18/93	LAMINATE 300F/3 TONS							
		223-1A	0.54	0.044	4.8317824	0.55	0.045	4.811898513	-0.41152263
		223-2A	0.49	0.044	4.3843951	0.7	0.044	6.263421618	42.8571429
		223-3A(WI)	.470/.620	0.044	5.54	1.15	0.045	10.06124234	81.6108726
		223-4A(WI)	.440/.450	0.045	3.93	1	0.044	8.947745168	127.677994
224A	10/19/93	FIRST WITHOUT SCW, SECOND WITH LAMINATE 350F/3 TONS							
		224-1A	1.7	0.08	8.3661417				

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
225A	10/20/93	LAMINATE 300F/3 TONS (TTS)225-1A (TTS)225-2A (138S)225-3A (138S)225-4A	1.65		0.08		8.1200787								
				1.7		0.08		8.3661417							
				1.65		0.08		8.1200787							
				1.6		0.081		7.7768057							
				1.75		0.08		8.6122047							
				1.85		0.08		9.1043307							
				1.8		0.08		8.8582677							
				2		0.081		9.7210071							
				1.8		0.081		8.7489064							
*SAMPLES SURFACE TREATED															
226A	10/21/93	LAMINATE 300F/3 TONS (TTS)226-1A (TTS)226-2A (138S)226-3A (138S)226-4A (30 DAYS)226-3A	0.175		0.046		1.4977747		0.36		0.045		3.149606299		110.285714
			0.195		0.045		1.7060367		0.46		0.044		4.115962777		141.258741
			0.235		0.046		2.0112975		0.285		0.045		2.49343832		23.9716312
			0.21		0.045		1.8372703		0.245		0.046		2.096884629		14.1304348
227A	10/22/93	LAMINATE 300F/3 TONS 227-1A 227-2A 227-3A 227-4A	0.14		0.028		1.9685039		100		0.028		1406.074241		71328.5714
			0.16		0.028		2.2497188		100		0.028		1406.074241		62400
			0.23		0.028		3.2339708		0.23		0.028		3.233970754		0
			0.28		0.027		4.082823		0.34		0.029		4.615802335		13.0541872
			0.23		0.028		3.2339708		0.28		0.028		3.937007874		21.7391304
228A	10/25/93	LAMINATE 300F/3 TONS 228-1A(TTS) 228-1A(TTS) 228-3A(138S) 228-4A(138S)	0.84		0.044		7.5161059		0.9		0.044		8.052970651		7.14285714
			0.96		0.043		8.789599		1.15		0.043		10.5292071		19.7916667
			0.94		0.044		8.4108805		1.1		0.044		9.842519685		17.0212766
			0.94		0.043		8.6064823		1		0.045		8.748906387		1.65484634
229A	10/26/93	LAMINATE 300F/3 TONS 229-1A(TTS) 229-1A(TTS) 229-3A(138S) 229-4A(138S)	0.35		0.046		2.9955495		0.73		0.046		6.247860322		108.571429
			0.3		0.045		2.6246719		0.67		0.045		5.861767279		123.333333
			0.47		0.045		4.111986		0.62		0.045		5.42432196		31.9148936
			0.44		0.045		3.8495188		0.54		0.045		4.724409449		22.7272727

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
230A	10/29/93	LAMINATE 300F/3 TONS													
		230-1A(TTS)	0.29	0.044	0.044	0.044	2.5948461	0.68	0.68	0.044	0.044	6.084466714	134.482759		
		230-1A(TTS)	0.31	0.043	0.043	0.044	2.838308	0.59	0.59	0.044	0.044	5.279169649	85.9970674		
		230-3A(138S)	0.45	0.043	0.043	0.044	4.1201245	0.52	0.52	0.044	0.044	4.652827487	12.9292929		
		230-4A(138S)	0.34	0.044	0.044	0.044	3.0422334	0.42	0.42	0.044	0.044	3.758052971	23.5294118		
138S															
231A	10/29/93	LAMINATE 300F/3 TONS													
		231-1A(TTS)	0.41	0.044	0.044	0.044	3.6885755	1.3	1.3	0.044	0.044	11.63206872	217.073171		
		231-1A(TTS)	0.32	0.044	0.044	0.045	2.8632785	2.2	2.2	0.045	0.045	19.24759405	572.222222		
		231-3A(138S)	0.49	0.044	0.044	0.044	4.3843951	0.68	0.68	0.044	0.044	6.084466714	38.7755102		
		231-4A(138S)	0.52	0.044	0.044	0.044	4.6528275	0.65	0.65	0.044	0.044	5.816034359	25		
232A	10/29/93	LAMINATE 300F/3 TONS													
		232-1A(TTS)	0.34	0.044	0.044	0.044	3.0422334								
		232-1A(TTS)	0.36	0.044	0.044	0.044	3.2211883								
		232-3A(138S)	0.57	0.044	0.044	0.044	5.1002147	0.71	0.71	0.044	0.044	6.352899069	24.5614035		
		232-4A(138S)	0.58	0.044	0.044	0.044	5.1896922	0.62	0.62	0.044	0.044	5.547602004	6.89655172		
233A	10/29/93	LAMINATE 300F/3 TONS													
		233-1A(TTS)	0.22	0.045	0.045	0.045	1.9247594								
		233-1A(TTS)	0.23	0.044	0.044	0.044	2.0579814								
		233-3A(138S)	0.28	0.044	0.044	0.044	2.5053686	2.25	2.25	0.044	0.044	20.13242663	703.571429		
		233-4A(138S)	0.35	0.045	0.045	0.045	3.0621172	1.2	1.2	0.044	0.044	10.7372942	250.649351		
234A	11/7/93	LAMINATE 300F/3 TONS													
		234-1A(TTS)	0.45	0.044	0.044	0.044	4.0264853								
		234-1A(TTS)	0.46	0.044	0.044	0.044	4.1159628								
		234-3A(138S)	0.5	0.044	0.044	0.044	4.4738726	1.05	1.05	0.044	0.044	9.395132427	110		
		234-4A(138S)	0.64	0.044	0.044	0.044	5.7265569	1.35	1.35	0.043	0.043	12.36037356	115.843023		
235A	11/7/93	LAMINATE 300F/3 TONS													
		235-1A(TTS)	0.46	0.044	0.044	0.044	4.1159628								
		235-1A(TTS)	0.44	0.044	0.044	0.044	3.9370079								
		235-3A(138S)	0.76	0.044	0.044	0.044	6.8002863	0.66	0.66	0.044	0.044	5.905511811	-13.1578947		
		235-4A(138S)	0.68	0.044	0.044	0.044	6.0844667	0.7	0.7	0.044	0.044	6.263421618	2.94117647		
236A	11/7/93	LAMINATE 300F/3 TONS													
		236-1A(TTS)	0.68	0.033	0.033	0.033	8.1126223								

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER		
237A	11/7/93	LAMINATE 300F/3 TONS 237-1A(TTS) 237-1A(TTS) 237-3A(138S) 237-4A(138S)	0.8	0.031	10.16002	1.3	0.043	11.90258194	23.8095238		0.043	11.90258194	23.8095238	
			1.05	0.043	9.6136239	1.2	0.044	10.7372942	20.5741627		0.044	10.7372942	20.5741627	
			0.95	0.042	8.9051369									
238A	11/7/93	LAMINATE 300F/3 TONS 238-1A 238-2A 238-3A 238-4A	0.67	0.043	6.1344076									
			0.8	0.044	7.1581961									
			0.67	0.043	6.1344076	0.96	0.044	8.589835361	40.027137		0.044	8.589835361	40.027137	
			0.49	0.044	4.3843951	1.2	0.044	10.7372942	144.897959		0.044	10.7372942	144.897959	
239A	11/10/93	LAMINATE 300F/3 TONS 239-1A 239-2A 239-3A 239-4A	0.42	0.044	3.758053	0.55	0.044	4.921259843	30.952381		0.044	4.921259843	30.952381	
			0.38	0.045	3.3245844	0.4	0.045	3.499562555	5.26315789		0.045	3.499562555	5.26315789	
			0.36	0.044	3.2211883	0.48	0.044	4.294917681	33.3333333		0.044	4.294917681	33.3333333	
			0.34	0.045	2.9746282	0.5	0.045	4.374453193	47.0588235		0.045	4.374453193	47.0588235	
240A	11/16/93	LAMINATE 300F/3 TONS 240-1A 240-2A 240-3A 240-4A	0.459	0.045	4.015748	0.64	0.045	5.599300087	39.4335512		0.045	5.599300087	39.4335512	
			0.39	0.045	3.4120735	0.45	0.045	3.937007874	15.3846154		0.045	3.937007874	15.3846154	
			0.45	0.045	3.9370079	0.79	0.045	6.911636045	75.5555556		0.045	6.911636045	75.5555556	
			0.44	0.044	3.9370079	0.58	0.044	5.189692198	31.8181818		0.044	5.189692198	31.8181818	
241A	11/15/93	LAMINATE 300F/3 TONS 241-1A 241-2A 241-3A	0.54	0.045	4.7244094	0.64	0.045	5.599300087	18.5185185		0.045	5.599300087	18.5185185	
			0.66	0.044	5.9055118									
			0.6	0.045	5.2493438	0.84	0.044	7.516105941	43.1818182		0.044	7.516105941	43.1818182	
			0.77	0.044	6.8897638									
242A	11/18/93	LAMINATE 300F/3 TONS 242-1A 242-2A 242-3A 242-4A(NO PB)	0.72	0.077	3.681358									
			0.78	0.077	3.9881378									
			0.79	0.076	4.0924161									
243A	11/18/93	LAMINATE 300F/3 TONS 243-1A	0.59	0.066	3.5194464									
			0.64	0.066	3.8177046									
			0.67	0.067	3.9370079									
			0.72	0.066	4.2949177									

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
244A	11/18/93	LAMINATE 300F/3 TONS 243-2A 243-3A 242-4A(NO PB)	0.42	2.4679751	0.067	FOR BATTERY BUILD									
			0.41	2.445717	0.066										
			0.41	2.4092138	0.067										
245A	12/11/93	LAMINATE 300F/3 TONS 244-1A 244-2A 244-3A 244-4A(NO PB)	0.56	3.3404915	0.066	FOR BATTERY BUILD									
			0.49	2.9229301	0.066	ACTIVE SIDE WITH NEG PASTE									
			0.5	2.9825817	0.066										
			0.49	2.9229301	0.066										
246A	12/13/93	LAMINATE 300F/3 TONS 245-1A 245-2A 245-3A 245-4A	0.59	5.6654504	0.041		0.62	0.041	5.953524102	0.041	5.953524102	5.08474576	5.953524102	5.08474576	
			0.55	5.1556055	0.042		0.71	0.041	6.817745343	0.041	6.817745343	32.2394678	6.817745343	32.2394678	
			0.66	6.3376224	0.041		0.77	0.041	7.393892837	0.041	7.393892837	16.6666667	7.393892837	16.6666667	
			0.7	6.7217208	0.041		1	0.04	9.842519685	0.04	9.842519685	46.4285714	9.842519685	46.4285714	
247A	12/13/93	LAMINATE 300F/3 TONS 246-1A 246-2A 246-3A 246-4A	0.6	12.432656	0.019	SAMPLE BROKE									
			0.42	9.1863517	0.018		0.5	0.018	10.93613298	0.018	10.93613298	19.047619	10.93613298	19.047619	
			0.54	11.189391	0.019		0.52	0.019	10.77496892	0.019	10.77496892	-3.7037037	10.77496892	-3.7037037	
			0.42	8.7028595	0.019		0.52	0.019	10.77496892	0.019	10.77496892	23.8095238	10.77496892	23.8095238	
248A	12/27/93	LAMINATE 300F/3 TONS 247-1A 247-2A 247-3A 247-4A	0.285	5.6102362	0.02		0.39	0.02	7.677165354	0.02	7.677165354	36.8421053	7.677165354	36.8421053	
			0.34	6.6929134	0.02		0.38	0.021	7.124109486	0.021	7.124109486	6.44257703	7.124109486	6.44257703	
			0.36	7.0866142	0.02		0.52	0.02	10.23622047	0.02	10.23622047	44.444444	10.23622047	44.444444	
			0.31	6.1023622	0.02		0.45	0.02	8.858267717	0.02	8.858267717	45.1612903	8.858267717	45.1612903	
249A	1/5/94	LAMINATE 300F/3 TONS 248-1A 248-2A 248-3A 248-4A	0.52	10.774969	0.019		1	0.019	20.72109407	0.019	20.72109407	92.3076923	20.72109407	92.3076923	
			0.4	8.7489064	0.018		0.66	0.018	14.43569554	0.018	14.43569554	65	14.43569554	65	
			0.48	9.4488189	0.02		1	0.02	19.68503937	0.02	19.68503937	108.333333	19.68503937	108.333333	
			0.46	10.061242	0.018		0.66	0.019	13.67592209	0.019	13.67592209	35.9267735	13.67592209	35.9267735	
249A	1/5/94	LAMINATE 300F/3 TONS 249-1A 249-2A 249-3A 249-4A	0.88	17.322835	0.02		0.8	0.02	15.7480315	0.02	15.7480315	-9.09090909	15.7480315	-9.09090909	
			0.38	7.8740157	0.019		0.34	0.019	7.045171985	0.019	7.045171985	-10.5263158	7.045171985	-10.5263158	
			0.38	7.8740157	0.019		0.42	0.019	8.702859511	0.019	8.702859511	10.5263158	8.702859511	10.5263158	
			0.4	7.8740157	0.02		0.44	0.02	8.661417323	0.02	8.661417323	10	8.661417323	10	
250A	1/5/94	LAMINATE 300F/3 TONS 250-1A 250-2A	*SAMPLE NOT SANDED PRIOR TO LAMINATION												
			0.88	8.4501632	0.041		0.84	0.041	8.066064913	0.041	8.066064913	-4.54545455	8.066064913	-4.54545455	
			0.5	4.8012291	0.041		0.46	0.041	4.417130785	0.041	4.417130785	-8	4.417130785	-8	

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
251A	1/5/94	LAMINATE 300F/3 TONS 251-1A 251-2A	0.19 0.225	0.041 0.041	1.8244671 2.1605531	0.24 0.23	0.041 0.041	2.304589975 2.208565393	26.3157895 2.2222222
252A	1/7/94	LAMINATE 300F/3 TONS 252-1A 252-2A	0.15 0.125	0.041 0.042	1.4403687 1.1717285	0.195 0.18	0.041 0.042	1.872479355 1.687289089	30 44
253A	1/7/94	LAMINATE 300F/3 TONS 253-1A 253-2A(30 TONS)	0.15 0.155	0.019 0.011	3.1081641 5.547602	0.245 0.11	0.02 0.01	4.822834646 4.330708661	55.1666667 -21.9354839
254A	1/12/94	LAMINATE 300F/3 TONS 254-1A 254-2A 254-3A 254-4A	0.38 0.4 0.46 0.5	0.021 0.021 0.02 0.021	7.1241095 7.4990626 9.0551181 9.3738283	0.32 0.48 0.64 0.6	0.021 0.021 0.02 0.021	5.999250094 8.998875141 12.5984252 11.24859393	-15.7894737 20 39.1304348 20
255A	1/20/94	LAMINATE 300F 3 TONS(30 TONS) 255-1A(3 TONS) 255-2A(3 TONS) 255-3A(30 TONS) 255-4A(30 TONS)	0.3 0.29 0.28 0.235	0.016 0.019 0.011 0.011	7.3818898 6.0091173 10.021475 8.4108805	0.265 0.28 0.32 0.295	0.016 0.019 0.011 0.011	6.520669291 5.801906341 11.45311382 10.5583393	-11.6666667 -3.44827586 14.2857143 25.5319149
256A	1/20/94	LAMINATE 300F/3 TONS NO SHIM 256-1A 256-2A 256-3A 256-4A	0.44 0.62 0.41 0.45	0.018 0.019 0.019 0.019	9.623797 12.847078 8.4956486 9.3244923	0.79 1.3 0.78 0.9	0.018 0.019 0.019 0.019	17.27909011 26.9374223 16.16245338 18.64898467	79.5454545 109.677419 90.2439024 100
257A	1/24/94	LAMINATE 300F/3 TONS .045" .031" SHIM 257-1A 257-2A 257-3A 257-4A 257-5A	0.76 0.74 0.8 0.9 0.77	0.04 0.04 0.04 0.041 0.04	7.480315 7.2834646 7.8740157 8.6422124 7.5787402				

1AKE BATTERY #257 (12V)
FULL PDSHEET

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)	
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER		
STABILITY TESTING																
258A	1/25/94	257-6A	0.73	0.028	10.264342	0.91	0.028	12.79527559	24.6575342							
		257-7A	0.79	0.028	11.107987	1.2	0.029	16.29106706	46.6608468							
		LAMINATE 300F/3 TONS														
		.045" .031" SHIM														
		258-1A	0.36	0.041	3.456885	OR BATTERY #258 4V										
		258-2A	0.4	0.042	3.7495313	CRACKED DURING ASSEMBLY										
		258-3A	0.34	0.034	3.9370079	OR BATTERY #258 4V										
STABILITY TESTING																
259A	1/26/94	258-4A	0.295	0.029	4.0048873	0.36	0.029	4.867320119	22.0338983							
		258-5A	0.33	0.029	4.4800434	0.4	0.029	5.430355688	21.2121212							
		LAMINATE 300F/3 TONS														
		.045" .031" SHIM														
		259-1A	0.71	0.041	6.8177453											
		259-2A	0.78	0.043	7.1415492											
		259-3A	0.6	0.041	5.7614749	N UPON PRESSING IN THE PB SHEET										
260A	2/4/94	259-4A	0.69	0.04	6.7913386											
		259-5A	0.7	0.042	6.5616798											
		259-6A	0.7	0.029	9.5031225											
		STABILITY TESTING														
		259-7A	0.51	0.026	7.7225924	0.48	0.026	7.268322229	-5.88235294							
		259-8A	0.51	0.027	7.4365704	0.54	0.027	7.874015748	5.88235294							
		LAMINATE 300F/3 TONS														
261A	2/4/94	.045" .031" SHIM														
		260-1A	0.56	0.041	5.3773766	DOUG-										
		260-2A	0.49	0.042	4.5931759	TO MAKE 4V BATTERY										
		260-3A	0.35	0.03	4.5931759	AMINATE BROKE										
		STABILITY TESTING														
		260-4A	0.46	0.028	6.4679415	0.54	0.027	7.874015748	21.7391304							
		260-5A	0.34	0.026	5.1483949	0.49	0.026	7.419745609	44.1176471							
262A	2/4/94	LAMINATE 300F/3 TONS														
		.045" .031" SHIM														
		261-1A	0.41	0.042	3.8432696	ULD NOT STICK TO LAMINATE										
		261-2A	0.42	0.042	3.9370079	"										
		261-3A	0.42	0.03	5.511811	"										
		STABILITY TESTING														
		261-4A	0.43	0.026	6.5112053	0.38	0.026	5.754088431	-11.627907							
262A	2/4/94	261-5A	0.44	0.026	6.6626287	0.46	0.025	7.244094488	8.72727273							
		LAMINATE 375F/3 TONS														
		NO SHIM														
		262-1A	0.52	0.017	12.042612	0.74	0.016	18.20866142	51.2019231							
		262-2A	0.6	0.017	13.895322	0.72	0.016	17.71653543	27.5							
		262-3A	0.53	0.017	12.274201	0.69	0.016	16.97834646	38.3254717							
		262-4A	0.51	0.017	11.811024	0.63	0.016	15.5019685	31.25							

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
263A	2/1/94	LAMINATE 300F/3 TONS													
		0.045" SHIM													
		263-1A	0.5		0.043		4.5779161		ATTIRY #263 6V-FULL PB SHEET						
264A	2/4/94	LAMINATE 300F/3 TONS													
		0.031" SHIM													
		264-1A	0.46		0.034		5.3265401		MAKE BATTERY #264 4V						
265A	2/4/94	LAMINATE 300F/3 TONS													
		0.031" SHIM													
		265-1A	0.3		0.033		3.5790981		MAKE BATTERY #265-6V						
266A	2/18/94	LAMINATE 300F/3 TONS													
		0.051" SHIM													
		266-1A	0.36		0.046		3.0811366		0.37		0.045		3.237095363		5.0617284
267A	3-3-94	LAMINATE 300F/3 TONS													
		267-1A(C)	0.52		0.039		5.2493438		0.73		0.044		6.531853973		W/PB SHEET
		267-2A(P)	0.61		0.037		6.4907427		0.6		0.041		5.761474938		"
268A	3-3-94	LAMINATE 300F/3 TONS													
		268-1A	0.57		0.042		5.3430821		0.66		0.045		5.774278215		W/PB SHEET

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE		THICKNESS		RESISTIVITY		RESISTANCE		THICKNESS		RESISTIVITY		PERCENT CHANGE
			(OHM) BEFORE	(OHM) AFTER	(INCH) BEFORE	(INCH) AFTER	(OHM-CM) BEFORE	(OHM-CM) AFTER	(OHM) BEFORE	(OHM) AFTER	(INCH) BEFORE	(INCH) AFTER	(OHM-CM) BEFORE	(OHM-CM) AFTER	
269A	3/3/94	LAMINATE 300F/3 TONS	0.6	0.65	0.045	0.046	5.2493438	5.5631633							"
			0.53	0.58	0.044	0.046	4.7423049	4.964053406							"
			0.49	0.57	0.044	0.046	4.3843951	4.878466279							"
			0.54	0.62	0.04	0.047	5.3149606	5.193499749							"
				0.49		0.048		4.019028871							INATED, PB SHE
				0.46		0.048		3.772965879							"
				0.5		0.049		4.017354973							"
															"
270A	3/4/94	LAMINATE 300F/3 TONS		0.46		0.048		3.772965879							"
				0.94		0.045		8.223972003							"
			0.52	0.54	0.043	0.044	4.7610328	4.831782391							1.48601399
			0.48	0.56	0.043	0.044	4.3947995	5.010737294							14.0151515
			0.6	0.81	0.025	0.027	9.4488189	11.81102362							25
			0.44	0.6	0.028	0.028	6.1867267	8.436445444							36.3636364
			0.55	0.68	0.028	0.028	7.7334083	9.561304837							23.6363636
			0.36	0.6	0.021	0.021	6.7491564	11.24859393							66.6666667
271A	3/10/94	LAMINATE 300F/3 TONS													
			0.94	0.35	0.018	0.018	20.55993	7.655293088							-62.7659574
			0.824	0.98	0.022	0.022	14.745884	17.53758053							18.9320388
			0.745		0.02		14.665354	PLASTIC CRACKED							
			0.4	0.44	0.018	0.018	8.7489064	9.623797025							10
			0.59	0.74	0.022	0.021	10.558339	13.87326584							31.3962873
			0.37	0.39	0.02	0.02	7.2834646	7.677165354							5.40540541
			0.34	0.31	0.02	0.02	6.6929134	6.102362205							-8.82352941
272A	3/17/94	LAMINATE 300F/3 TONS	0.245	0.43	0.019	0.02	5.076668	8.464566929							66.7346939
			0.345	0.35	0.02	0.022	6.7913386	6.263421618							-7.77338603
			0.3	0.58	0.028	0.027	4.2182227	8.457276174							100.493827
			0.33	0.65	0.028	0.028	4.640045	9.139482565							96.969697
			0.36	0.43	0.028	0.028	5.0618673	6.046119235							19.4444444
			0.36	0.41	0.028	0.028	5.0618673	5.764304387							13.8888889
				0.94		0.041		9.026310736							141.335045
			0.38	0.72	0.04	0.04	3.7401575	7.086614173							111.764706
273A	3/17/94	LAMINATE 300F/3 TONS	0.34	0.65	0.04	0.041	3.3464567	6.241597849							66.6666667
			0.39	0.52	0.041	0.041	3.7449587	4.993278279							43.9683586
			0.37	0.52	0.042	0.041	3.4683165								
				9		0.054		65.6167979							209.52381
			2.8	10	0.052	0.059	21.199273	66.72894702							227.683616
			3		0.058		20.363834								
274A	4/28/94	LAMINATE 300F/3 TONS													

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
275A	4/28/94	LAMINATE 300F/3 TONS 275-1A 275-2A	2.65		0.044		23.711525		24.5		0.044		219.2197566		824.528302
			1.95		0.042		18.278965		50		0.044		447.3872584		2347.55245
276A	4/28/94	LAMINATE 300F/3 TONS 276-1A 276-2A	3.2		0.06		20.997375		6.8		0.064		41.83070866		99.21875
			3.8		0.06		24.934383		5		0.062		31.7500635		27.3344652
277A	5/2/94	LAMINATE 300F/3 TONS 277-1A 277-2A 277-3A 277-4A	0.58		0.047		4.8584352		3R 4V BATTERY		277-1 C				
			NA		0.041		NA		3R 4V BATTERY		277-2 C				
			NA		0.042		NA		4R 6V BATTERY		277-6V C				
			NA		0.042		NA		"		"				
278A	5/2/94	LAMINATE 300F/3 TONS 278-1A 278-2A 278-3A	NA		0.04		NA		3R 4V BATTERY		278-1 C				
			NA		0.039		NA		4R 6V BATTERY		278-6V C				
			NA		0.04		NA		"		"				
279A	5/2/94	LAMINATE 300F/3 TONS 279-1A 279-2A 279-3A 279-4A	NA		0.042		NA		3R 4V BATTERY		279-1 C				
			NA		0.039		NA		3R 4V BATTERY		279-2 C				
			NA		0.04		NA		4R 6V BATTERY		279-6V C				
			NA		0.039		NA		"		"				
280A	5/9/94	LAMINATE 300F/3 TONS 280-1A 280-2A 280-3A 280-4A	0.38		0.035		4.2744657		2.75		0.037		29.26154501		584.566145
			0.31		0.039		3.1294165		8.1		0.04		79.72440945		2447.58065
			0.28		0.035		3.1496063		3		0.037		31.92168546		913.513514
			0.3		0.035		3.3745782		2.3		0.037		24.47329219		625.225225
281A	5/12/94	LAMINATE 300F/3 TONS 281-1A 281-2A	0.43		0.033		5.1300406		3R 4V BATTERY		281-1 C				
			0.41		0.035		4.6119235		3R 4V BATTERY		281-2 C				

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
282A	5/13/94	LAMINATE 300F/3 TONS 281-3A 281-4A	0.3 0.36	0.034 0.034	3.4738305 4.1685966	R 6V BATTERY " "	281-6V C "		
			0.4 0.42 0.38 0.4	0.035 0.037 0.036 0.036	4.4994376 4.469036 4.1557305 4.3744532	3R 4V BATTERY 3R 4V BATTERY R 6V BATTERY "	282-1 C 282-2 C 282-6V C "		
283A	5/13/94	LAMINATE 300F/3 TONS 283-1A 283-2A 283-3A 283-4A	0.52 0.5 0.45 0.36	0.025 0.025 0.025 0.024	8.1889764 7.8740157 7.0866142 5.9055118	2.85 2.35 3.3 2.5	0.025 0.025 0.025 0.024	44.88188976 37.00787402 51.96850394 41.01049869	448.076923 370 633.333333 594.444444
284A	5/25/94	LAMINATE 300F/3 TONS 284-1A 284-2A 284-3A 284-4A	0.5 0.54 0.55 0.7	0.041 0.041 0.041 0.04	4.8012291 5.1853274 5.281352 6.8897638	1.1 1.4 1.6 1.6	0.041 0.041 0.041 0.041	10.56270405 13.44344152 15.36393317 15.36393317	120 159.259259 190.909091 122.996516
285A	6/2/94	LAMINATE 300F/3 TONS 285-1A 285-2A 285-3A 285-4A	0.89 1.15 1.25 1.35	0.045 0.046 0.048 0.047	7.7865267 9.8425197 10.252625 11.308427	OR 4V BATTERY OR 4V BATTERY OR 4V BATTERY OR 4V BATTERY	285-1 286-2 287-3 288-4		
286A	6/2/94	LAMINATE 300F/3 TONS 286-1A 286-2A 286-3A 286-4A	1.1 1.25 1.05 1.25	0.047 0.049 0.05 0.051	9.2142737 10.043387 8.2677165 9.6495291	DON'T USE OR 4V BATTERY DON'T USE DON'T USE	286-2 287-3 288-4 289-5		
287A	6/3/94	LAMINATE 300F/3 TONS 287-1A 287-2A 287-3A 287-4A	0.9 0.6 0.595 0.53	0.047 0.043 0.044 0.043	7.5389512 5.4934994 5.3239084 4.8525911	DON'T USE OR 4V BATTERY OR 4V BATTERY OR 4V BATTERY	287-1 287-2 287-3 288-4		
288A	6/15/94	LAMINATE 300F/3 TONS 288-1A	0.66	0.041	6.3376224	E, SUBSTRATE CRACKED			

SAMPLE NUMBER	TEST DATE	MATERIAL COMPOSITION	RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		RESISTANCE (OHM)		THICKNESS (INCH)		RESISTIVITY (OHM-CM)		PERCENT CHANGE (%)
			BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
289A	6/16/94	LAMINATE 300F/3 TONS 289-1A 289-2A 289-3A 289-4A	0.8		0.042		7.4990626		OR 4V BATTERY 288-2						
			0.54		0.041		5.1853274								
			0.92		0.042		8.623922								
290A	6/23/94	LAMINATE 300F/3 TONS 290-1A 290-2A 290-3A 290-4A 290-5A 290-6A 290-7A 290-8A 290-9A 290-10A 290-11A 290-12A	0.68		0.018		14.873141		OR 4V BATTERY 290-1						
			0.7		0.019		14.504766		OR 4V BATTERY 290-6V						
			0.62		0.019		12.847078		"						
			0.66		0.02		12.992126		"						
			0.52		0.02		10.23622		"						
			0.49		0.02		9.6456693		"						
			0.44		0.019		9.1172814		"						
			0.5		0.019		10.360547		"						
			0.5		0.021		9.3738283		"						
			0.5		0.021		9.3738283		"						
			0.52		0.021		9.7487814		"						
			0.54		0.021		10.123735		"						

APPENDIX B

DELIVERABLE DATA

BUILD ID

WPG-6

Description

12 V Bipolar Battery

ASSEMBLY

Substrate Type	5.9375" X 9.1875" X 0.012" tin-lead alloy sheet
Grid Type	0.016" thick metallic screen soldered to the substrate
Separator Type, Dimensions	5.125" X 8.562" X 0.029"
Positive Paste Density	3.35 g/cc
Negative Paste Density	3.75 g/cc

Plate ID	PTE D2	D5		D7		D8		D9		D10		NTE D4
Pb Mass (g.)	260.90	158.80		160.20		162.60		158.10		161.60		261.90
AM Mass (g.)	51.70	104.30		104.20		106.00		103.50		104.80		53.40
Dry AM (g.)	51.70	52.19	52.11	52.52	51.68	52.92	53.08	52.26	51.24	51.94	52.86	53.40
Sep. Mass (g.)	Cell 1	3.54	Cell 2	3.52	Cell 3	3.53	Cell 4	3.53	Cell 5	3.52	Cell 6	3.51

Termination	Copper stud soldered to terminal electrode
Containment Type	Solvent bonded ABS. Container core thickness = 0.668"
Completed Mass	3.5121 kg

FORMATION

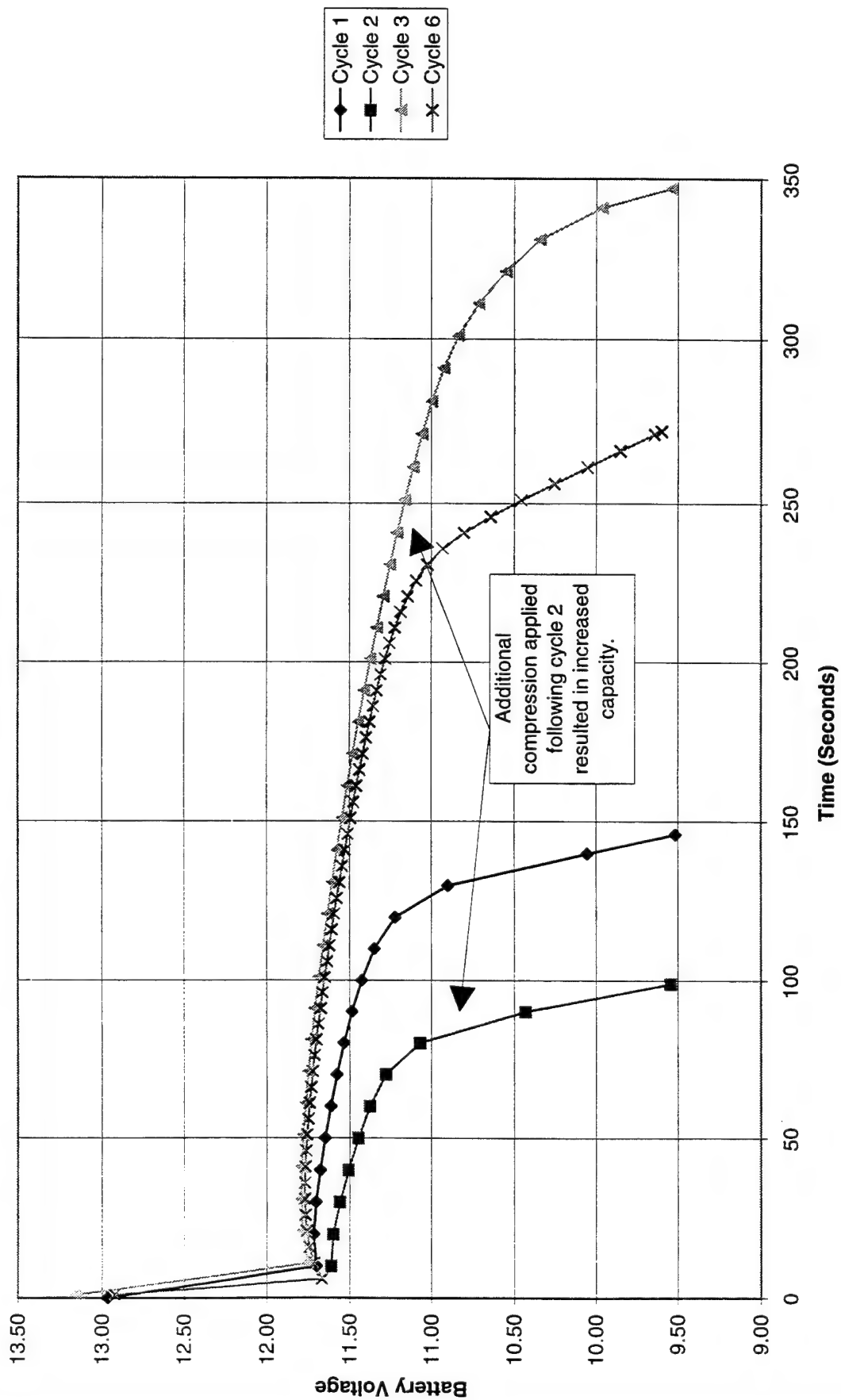
Acid Gravity	Chilled 1.265
% Sodium Sulfate	1.5
Method of Fill	Vacuum

Time	27H:55M:04S
Amps	1.0
Voltage Limit	16.32
Amp Hours	20.62
Watt Hours	311.8
Internal Resistance	13.5 mΩ

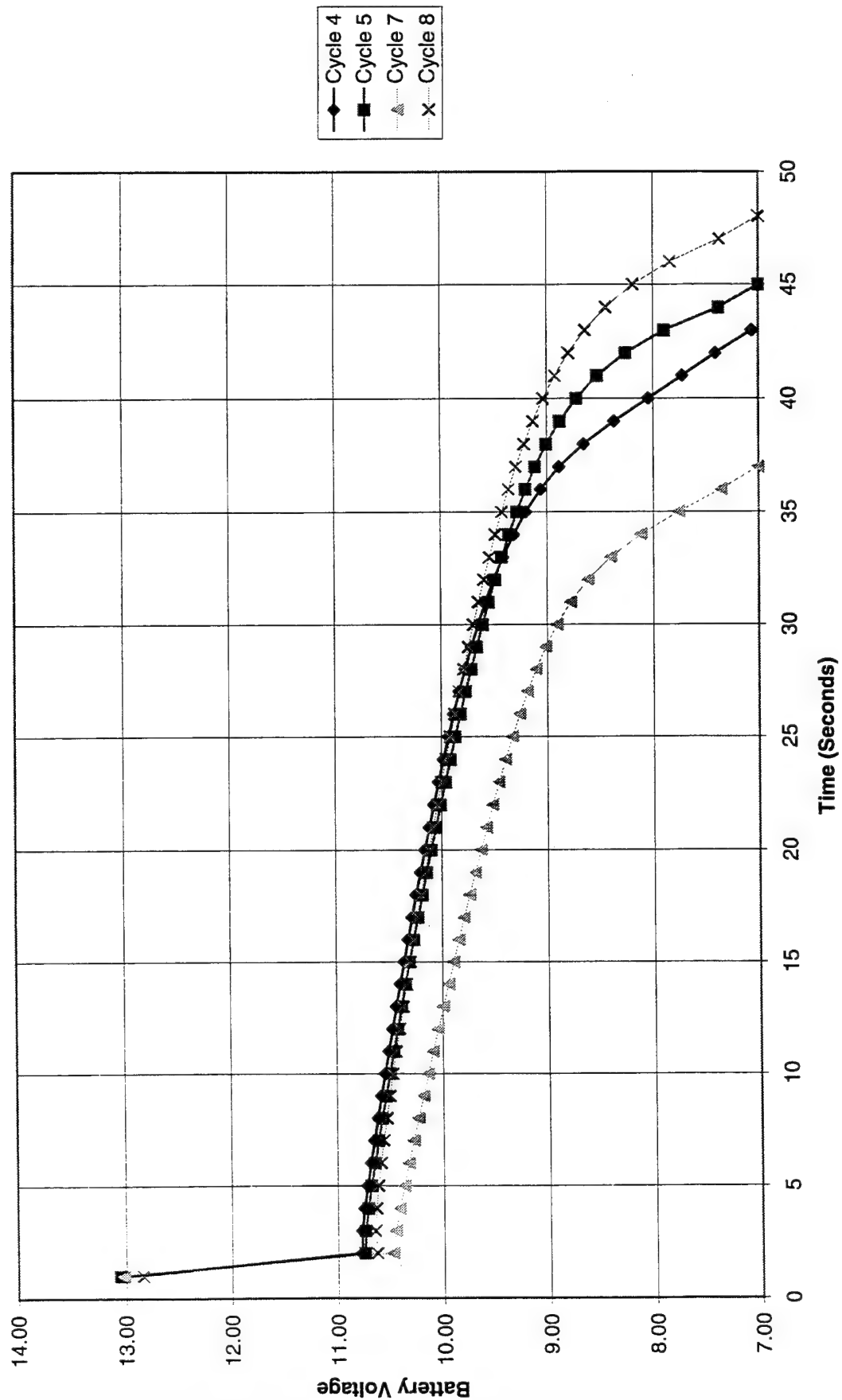
CYCLING HISTORY

Cycle	Date	IR (mW)	OCV	Discharge				Recharge				
				Amps	EODV	Ah	Wh	Amps	Vlimit	Ah	Wh	% Rchg
1	11/15/95	13.5	12.966	21	9.6	0.85	9.6	0.5	15.30	0.935	12.92	110
2	11/16/95	16.5	NA	21	9.6	0.57	6.4	0.1	14.40	NA	NA	NA
3	11/20/95	10.5	13.158	21	9.6	2.01	22.8	0.5	14.40	2.211	29.48	110
4	11/21/95	8.2	13.019	124	7.2	1.44	14.1	0.5	14.40	1.584	21.22	110
5	11/22/95	8.6	13.05	124	7.2	1.51	14.7	0.5	14.40	1.661	22.24	110
6	11/30/95	10.0	12.922	21	9.6	1.58	17.9	0.5	14.40	1.738	23.20	110
7	12/1/95	9.8	13.017	124	7.2	1.23	11.7	0.5	14.40	1.353	18.12	110
8	12/11/95	8.8	12.84	124	7.2	1.61	15.6	0.5	14.40	1.771	23.42	110

WPG-6 21 Amp Discharge Curves



WPG-6
124 Amp Discharge Curves



BUILD ID

WPG-8

Description

24 V Bipolar Battery

ASSEMBLY

Substrate Type 5.9375" X 9.1875" X 0.012" tin-lead alloy sheet

Grid Type 0.016" thick metallic screen soldered to the substrate

Separator Type, Dimensions 5.125" X 8.562" X 0.029"

Positive Paste Density 3.51 g/cc

Negative Paste Density 3.83 g/cc

Plate ID	PTE D54	D14		D15		D17		D18		D20		D21	
Pb Mass	258.70	162.90		162.20		161.90		162.80		163.10		162.00	
AM Mass	52.10	106.00		105.30		104.70		104.80		105.40		103.60	
Dry AM	52.10	52.71	53.29	52.41	52.89	52.65	52.05	52.33	52.47	52.37	53.03	51.85	51.75
Sep. Mass	Cell 1	3.52	Cell 2	3.53	Cell 3	3.48	Cell 4	3.52	Cell 5	3.48	Cell 6	3.47	Cell 7

Plate ID	D22		D23		D25		D26		D27		NTE D57
Pb Mass	160.40		163.10		160.90		161.90		162.80		258.50
AM Mass	103.20		102.00		106.00		101.70		103.30		54.00
Dry AM	52.05	51.15	51.24	50.76	51.22	54.78	50.75	50.95	51.51	51.79	54.00
Sep. Mass	3.49	Cell 8	3.46	Cell 9	3.49	Cell 10	3.50	Cell 11	3.51	Cell 12	3.50

Termination Copper stud soldered to terminal electrodes

Containment Type Solvent bonded ABS. Container core thickness = 1.153".

Containment Mass 5.5360 kg

FORMATION

Acid Gravity Chilled 1.265

% Sodium Sulfate 1.5

Method of Fill Vacuum

Time 20H:37M:03S

Amps 1.0

Voltage Limit 32.64

Amp Hours 20.62

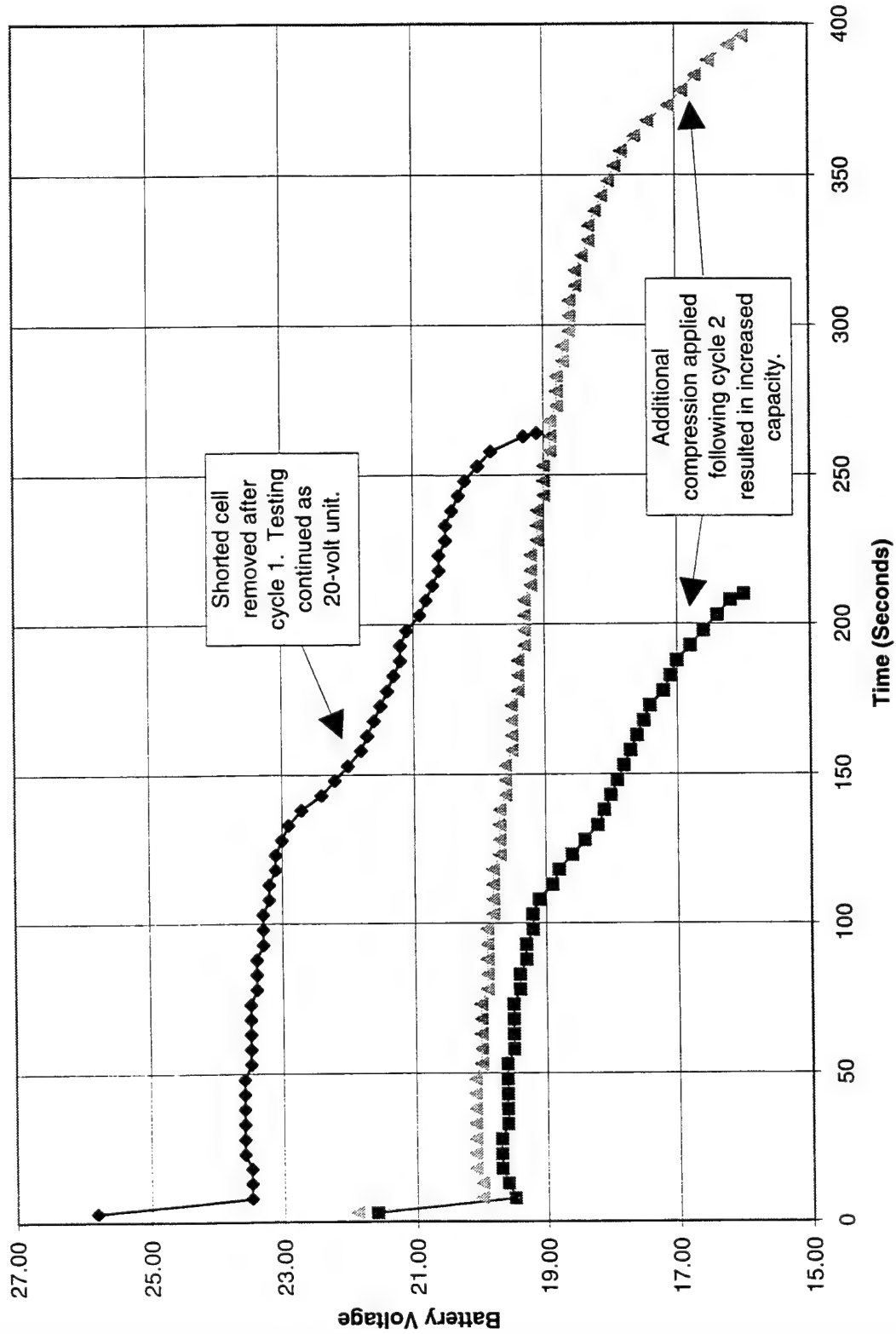
Watt Hours 594.0

Internal Resistance 14.0 mΩ

CYCLING HISTORY

Cycle	Date	IR (mV)	OCV	Discharge				Recharge				
				Amps	EODV	Ah	Wh	Amps	Vlimit	Ah	Wh	% Rchg
1	1/16/96	14.5	25.80	21	19.2	1.50	31	0.5	30.60	1.65	44	110
1/16/96 Two shorted bipolar electrodes removed. Continue cycling as 20-volt nominal battery.												
2	1/18/96	17.5	21.60	21	16.0	1.20	20	1.0	25.50	1.32	29	110
3	1/18/96	12.5	21.90	21	16.0	2.29	41	0.1	25.50	2.51	50	110
4	1/19/96	12.5	22.00	124	12.0	1.48	23	0.1	25.50	1.62	32	110
1/23/96 Two good bipolar electrodes added to stack to achieve 24-volt module.												
5	1/24/96	17.0	26.10	124	14.4	1.27	23	0.1	30.60	1.39	28	110
6	1/26/96	16.0	26.00	124	14.4	1.24	23	0.1	30.60	1.36	27	110

WPG-8 21 Amp Discharge Curves

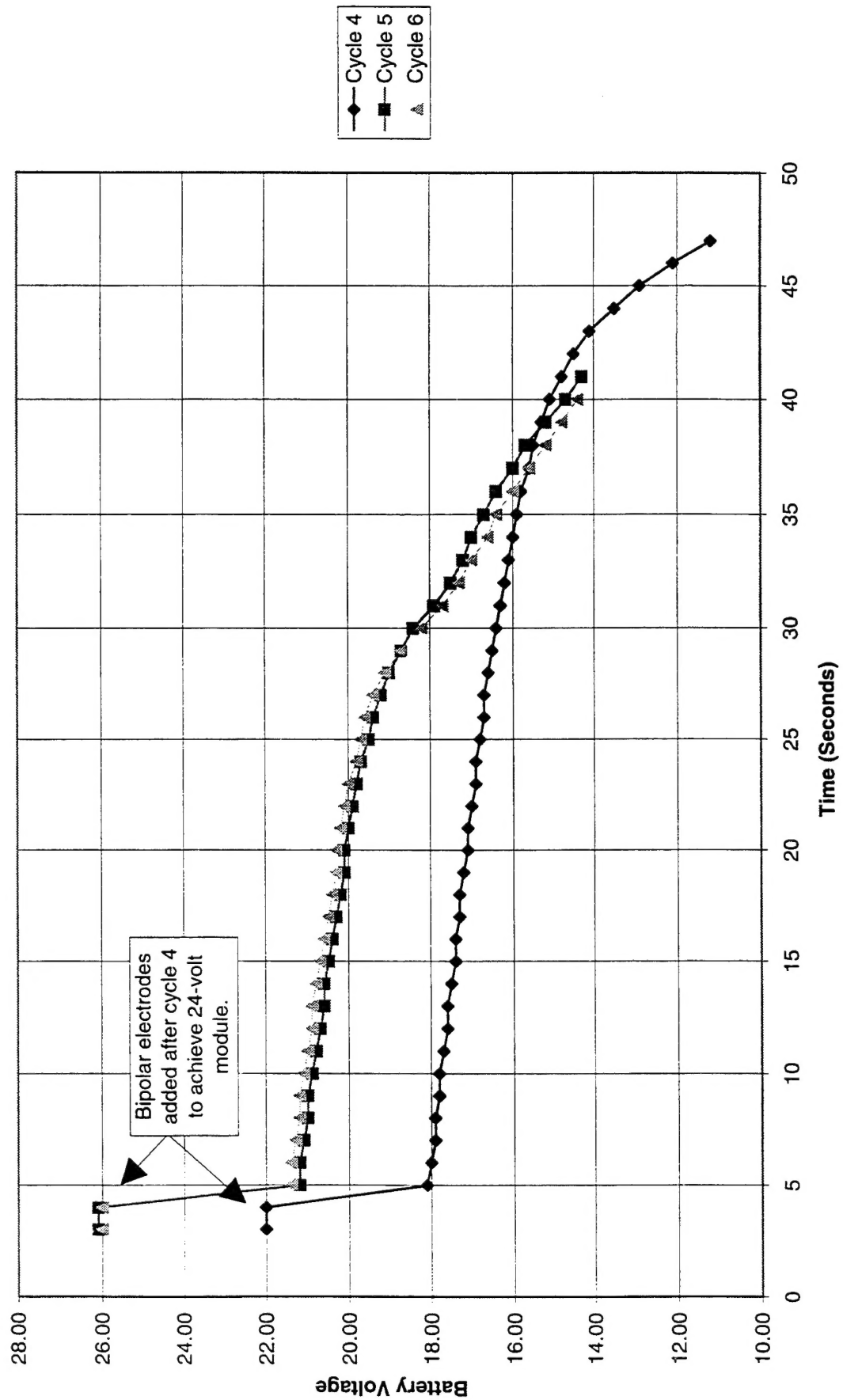


◆ Cycle 1
■ Cycle 2
▲ Cycle 3

Shorted cell removed after cycle 1. Testing continued as 20-volt unit.

Additional compression applied following cycle 2 resulted in increased capacity.

WPG-8 124 Amp Discharge Curves



BUILD ID

WPG-11

Description

12 V Bipolar Battery

ASSEMBLY

Substrate Type 5.9375" X 9.1875" X 0.012" tin-lead alloy sheet

Grid Type 0.016" thick metallic screen soldered to the substrate

Separator Type, Dimensions 5.125" X 8.562" X 0.029"

Positive Paste Density 3.40 g/cc

Negative Paste Density 3.75 g/cc

Plate ID	PTE D72	D66		D67		D69		D64		D65		NTE D74
Pb Mass (g.)	261.03	160.07		160.71		163.42		163.13		164.39		258.98
AM Mass (g.)	50.97	102.23		102.49		102.98		101.27		101.91		54.32
Dry AM (g.)	50.97	51.03	51.20	50.97	51.52	51.23	51.75	50.40	50.87	50.57	51.34	54.32
Sep. Mass (g.)	Cell 1	3.53	Cell 2	3.45	Cell 3	3.48	Cell 4	3.52	Cell 5	3.50	Cell 6	3.48

Termination Copper stud soldered to terminal electrode

Containment Type Solvent bonded ABS. Container core thickness = 0.671".

Containment Mass 3.4908 kg

FORMATION

Acid Gravity Chilled 1.265

% Sodium Sulfate 1.5

Method of Fill Vacuum

Time

Amps 1

Voltage Limit 16.32

Amp Hours 20.62

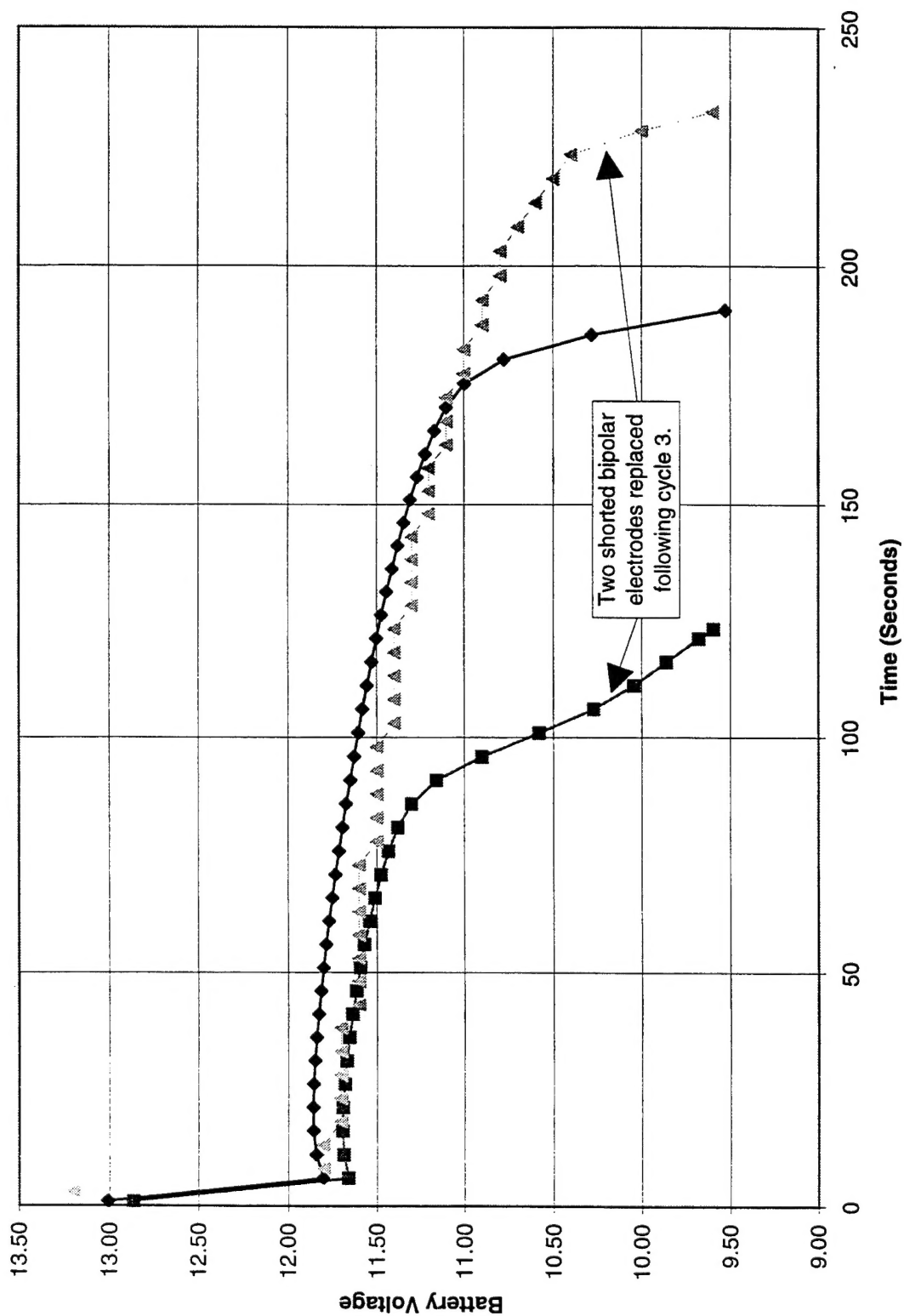
Watt Hours NA

Internal Resistance 12 mΩ

CYCLING HISTORY

Cycle	Date	IR (mW)	OCV	Discharge				Recharge				
				Amps	EODV	Ah	Wh	Amps	Vlimit	Ah	Wh	% Rchg
1	2/16/96	10.5	13.009	21	9.6	1.1	12.7	0.5	15.30	1.21	16.4	110
2	2/16/96	11.0	13.137	124	7.2	0.72	6.6	0.5	15.30	0.79	10.8	110
3	2/19/96	12.0	12.866	21	9.6	0.71	7.9	0.5	15.30	0.78	10.5	110
2/26/96 Replaced two shorted bipolar electrodes.												
4	2/27/96	11.5	13.200	21	9.6	1.33	12.0	0.5	14.40	1.46	17.0	110
5	2/28/96	11.0	13.005	124	7.2	0.82	7.0	0.5	14.40	0.90	10.0	110

WPG-11
21 Amp Discharge Curves



WPG-11
124 Amp Discharge Curves

